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Second Annual
Safar Symposium

SAFAR CENTER FOR RESUSCITATION RESEARCH

UNIVERSITY OF PITTSBURGH

Thursday, October 30, 2003

Biomedical Science Tower

South—Room S100A

February 2004 Supplement to: Volume 32, Number 2

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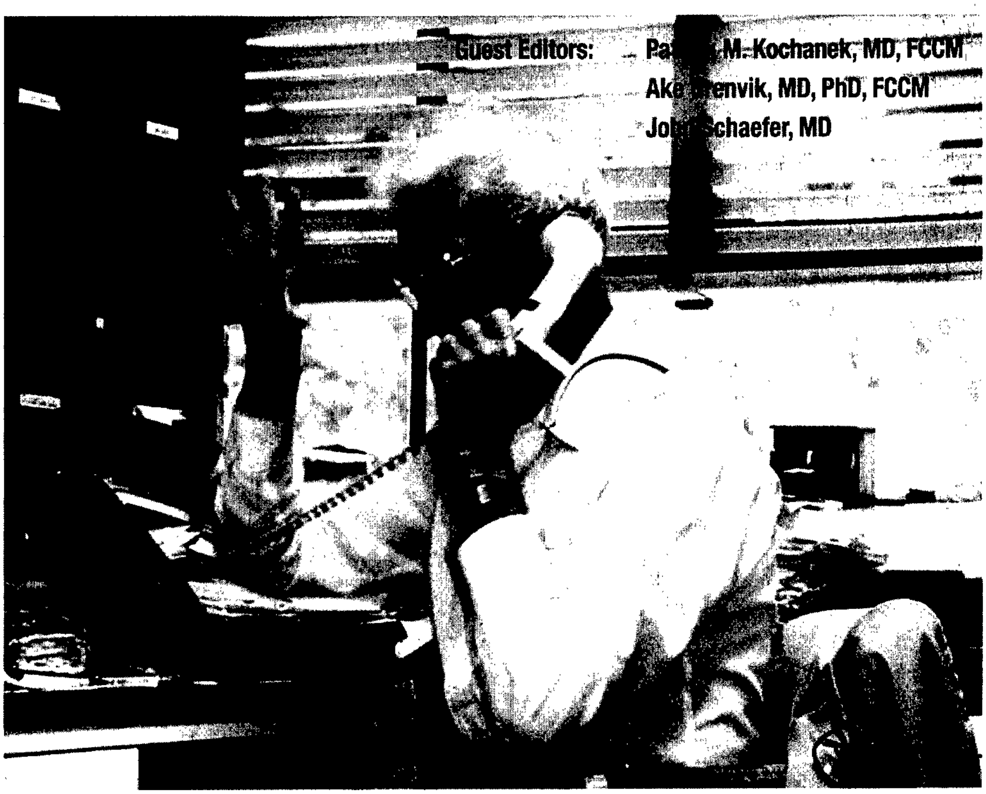

A Celebration of the Life of

Peter J. Safar, MD

and Proceedings of the
Second Annual Safar Symposium

Lippincott Williams & Wilkins

A SUPPLEMENT TO

Critical Care Medicine

OFFICIAL JOURNAL OF THE SOCIETY OF CRITICAL CARE MEDICINE

February 2004 Volume 32, Number 2

GUEST EDITORS:

PATRICK M. KOCHANEK, MD, FCCM
AKE GRENVIK, MD, PHD, FCCM
JOHN SCHAEFER, MD

A CELEBRATION OF THE LIFE OF PETER J. SAFAR, MD, AND PROCEEDINGS OF THE SECOND ANNUAL SAFAR SYMPOSIUM

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A Celebration of the Life of

Peter J. Safar, MD

Featured on the cover is a photo of Dr. Peter Safar hard at work on a typical day in his office at the Safar Center.

Featured above is the image "The Doc" which was used as part of an award presented on October 30, 2003, by the United States Army Medical Research and Materiel Command to Mrs. Eva Safar in recognition of Dr. Peter Safar's important contributions to combat casualty care. This image is from the Angels Among Us series that was designed by Blessings Expressions of Faith (www.blessings-catalog.com), and is reproduced with their permission along with the permission of Mrs. Safar.

A special supplement for a very special man: A celebration of the life of Peter J. Safar, MD

Patrick M. Kochanek, MD, FCCM; Ake Grenvik, MD, PhD, FCCM; John Schaefer, MD

This special supplement to *Critical Care Medicine* honors Peter J. Safar, MD—a very special man in the fields of critical care, anesthesiology, emergency medicine, and disaster reanimatology, the collective fields that he called acute medicine. This supplement celebrates his incredible life through a number of articles, testimonials, memorials, letters, and historical photographs. We took great care to try to convey to you the remarkable scope of the creative genius of Peter Safar. The supplement also includes quotes from many colleagues and friends of Peter. Dr. Safar positively influenced an amazing number of people—and the stories that they tell provide us a glimpse of the genius, strength, passion, elegance, and humanism that he imparted. In addition, this supplement includes, in part, proceedings of the Second Annual Safar Symposium, which was held on October 30, 2003, at the University of Pittsburgh School of Medicine—part of what has become "Peter Safar Day" each year at the University of Pittsburgh.

We would like to thank the Laerdal Foundation and Mr. Hans Dahl for fully supporting the publication of this supplement. We are also deeply indebted to Mr. Tore Laerdal, president of Laerdal Medical, for his unwavering support of this project. Many of the things that Peter accomplished in his career would not have been possible without the support of the late Mr. Asmund Laerdal and, now, Mr. Tore Laerdal and the Laerdal Foundation. We will never forget the special friendship that defines the Safar-Laerdal legacy. We would also like to thank Fran Mistrick, Marci Provins, and Christopher Edwards in Pittsburgh and Lynn Retford and her staff in Chicago for their hard work in the preparation of this special project and Dr. Joseph Parrillo, John Ewers, and Deborah McBride for their suggestions and support.

We are honored to be able to assemble this tribute to our colleague, mentor, and dear friend.

From Safar Center for Resuscitation Research, Department of Critical Care Medicine (PMK, AG), and the Winter Institute for Simulation, Education, and Research, Department of Anesthesiology (JS), University of Pittsburgh School of Medicine, Pittsburgh, PA.

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The incredible career of Peter J. Safar, MD: The Michelangelo of acute medicine

Ake Grenvik, MD, PhD, FCCM; Patrick M. Kochanek MD, FCCM

Peter Safar was born April 12, 1924, in Vienna, Austria. He graduated from Piaristen Gymnasium in Vienna in 1942 at the height of the Second World War. After this, he was drafted into the German army by the Nazis, who were occupying Austria at the time. Threatened by deployment to the war zone against Russia, through manipulative ingenuity, Peter succeeded in acting up a mild eczema to a degree that made him unsuitable to serve on the war front. Thus, he had the opportunity to become a medical student at the University of Vienna in 1943. He graduated 5 yrs later. Choosing education in medicine was a natural decision for Peter, the son of two prominent Viennese physicians (1).

Peter Safar moved to the United States for further training. He first completed a year of surgical internship at Yale University and returned to Vienna during the summer of 1950. This is when he proposed to Eva Kyzivat, who became his lifetime partner and tireless supporter throughout their 53 yrs of eventful marriage. Peter started his anesthesia residency in 1950 in Robert Dripp's department at the Hospital of the University of Pennsylvania in Philadelphia. With James Eckenhoff, LeRoy VanDam, and John Severinghaus in Dripp's department, Peter had excellent influence by these prominent anesthesiologists in all areas of academic anesthesiology, including research. In addition, the renowned Julius Comroe served as chairman of the University of Pennsylvania Department of Physiology at that time.

From the Department of Critical Care Medicine (AG, PMK) and the Safar Center for Resuscitation Research (PMK), University of Pittsburgh, Pittsburgh, PA.

Key Words: Peter J. Safar; acute medicine; anesthesiology; resuscitation

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After his anesthesia residency, Peter and Eva were obliged by law to leave the United States for a couple of years to be permitted to apply for immigration status on return to the United States. They chose to go to Lima, Peru, where Peter started an anesthesia department at the National Oncology Hospital. In February 1954, he joined the anesthesia department at Johns Hopkins Hospital, and the next year moved to Baltimore City Hospital as Chief of Anesthesia. He served in this capacity for 6 yrs. It was here that Peter performed his daring studies on mouth-to-mouth ventilation of unconscious, paralyzed volunteers, mostly physician residents and nurses, who all trusted him to perform these risky investigations without any untoward consequences. These studies convincingly demonstrated the overwhelming superiority of mouth-to-mouth ventilation over the current arm-lift/chest-pressure techniques, which he showed not to move any air in and out of the lungs at all (2, 3).

Peter learned about the efficiency of exhaled-air ventilation in maintaining normal blood gases in nonbreathing, anesthetized patients during surgery from his friend James Elam (4). Peter called the technique, A for airway and B for breathing. He had previously learned to keep the airway open through backward tilt of the head, while pulling on the chin to move the obstructing tongue away from the posterior pharynx in unconscious patients (5). When Kouwenhoven's group at Hopkins, including Knickerbocker and Jude, described the efficiency of external cardiac compression in producing blood flow in patients with a nonbeating heart (6, 7), Peter quickly added this technique and thus established the ABC of cardiopulmonary resuscitation, with C standing for circulation (8).

Presentation of the new mouth-to-mouth ventilation technique at an international resuscitation congress in Norway in 1958 led to Peter's life-long friendship and collaboration with Bjorn Lind, then chief anesthesiologist in Stavanger, and Asmund Laerdal, an entrepreneur in Stavanger. These two Norwegians started work on a full-size mannequin for training of mouth-to-mouth resuscitation *ad modem* Peter Safar. Asmund Laerdal brought the prototype to Pittsburgh, and Peter recommended modifications, most importantly, a spring attachment inside the mannequin's chest to also permit external cardiac compression simulation. This mannequin became the world-conquering Resusci-Anne. The Stavanger-Pittsburgh association became a most fruitful collaboration, currently well into its second generation. The late Asmund Laerdal's son, Tore, assumed responsibility for their successful family business two decades ago. He has continued the traditional Laerdal generosity toward resuscitation research. Similarly, the leadership at what is now the Safar Center for Resuscitation Research was assumed by Patrick Kochanek in 1994.

Pittsburgh

In 1961, Peter was invited to Pittsburgh to consider the position as chief of anesthesiology at Presbyterian University Hospital. Although told that this was an impossible position, he accepted the challenge and so started Peter's Pittsburgh career that came to include so many important aspects of medicine. At the young age of 37, he began to develop what later became the largest academic department of anesthesiology in the United States from a very small start, with only three board-certified anesthesiologists on the faculty, including himself. In addition to Presbyterian University Hospital, Peter incorporated the anesthesiology services of Montefiore Hospital, The Eye and Ear Institute, Magee-Womens Hospital, Children's Hospital, and Veterans Administration Medical Center, all of which were located on the University campus. When Peter Safar, after 17 yrs, resigned as chairman of this huge department, the service covered approximately 60,000 surgical procedures per year, with >50 staff anesthesiologists and a large number of nurse anesthetists. The diversity of surgical cases and anesthetic procedures provided an excellent training program for the many anesthesiology residents in Peter's department.

In 1958, Peter Safar had already established a 16-bed general intensive care unit (ICU) in Baltimore, which probably was the first in the world to have 24-hr coverage by residents of different disciplines in house and staff physicians on backup call from home (9). He brought these experiences to Pittsburgh, where he initiated another general ICU with similar organization at Presbyterian University Hospital. In 1963, he introduced the first subspecialty training program for physicians in what was to become critical care medicine (10). Critical care medicine was then a division within the department of anesthesiology. Peter had concluded that every anesthesiologist who is skilled in managing operating-room patients in poor physical status should also be a reanimatologist and intensivist, for which purpose special training should be available in anesthesiology residencies. Although the first few trainees in the ICU at Presbyterian University Hospital were anesthesiologists, other physicians with different training backgrounds joined his program, such as Jan Smith of South Africa with training in internal medicine and pulmonology and Ake Grenvik from Sweden with his primary background in general surgery and cardiothoracic surgery. However, both of them also had additional training in anesthesiology.

Resuscitation Research

A very tragic event in the Safar family occurred in 1966 when Peter's and Eva's daughter Elizabeth developed a status asthmaticus, resulting in cardiac arrest. Cardiac function was restored, but she remained comatose and did not recover. This and other events in Peter's medical career increasingly made him realize that cardiopulmonary resuscitation must also include the brain. He coined the expression "cardiopulmonary cerebral resuscitation," with the acronym CPCR, which he championed. Increasingly, he concentrated his resuscitation research activities on methods to improve brain recovery after different forms of cardiac arrest. In the small research facilities within the anesthesia department at Presbyterian University Hospital, he established a research program that attracted both advanced and young anesthesiologists. Among the first to serve in Peter's laboratory were Drs. Bjorn Lind of Norway, James Snyder of Pittsburgh, who later became the chief of critical care medicine when Ake Grenvik stepped down in 1990, and Edwin Nemoto, who directed this laboratory for many years (11–13).

Resuscitation research activities were funded first locally and then through the Laerdal Foundation, National Institutes of Health, and eventually various branches of the Armed Forces of the United States. In 1978, Peter resigned from the chair of anesthesiology and founded his International Resuscitation Research Center (IRRC), located on the university campus in what previously was a casket factory (the A. F. Hill Casket Company). Peter jokingly referred to the transition from resurrection to resuscitation in that facility. Under his leadership, a myriad of resuscitation methods were scrutinized, initially testing a large number of promising brain-protective drugs.

Four different areas of activities were represented at IRRC for which Peter assigned the following associate directors: Nicholas Bircher (cardiac arrest laboratories), Norman Abramson (cardiac arrest clinical studies), Samuel Tisherman (shock/trauma), and Ernesto Pretto (disaster reanimatology). Research fellows from all over the world were attracted to the IRRC. Under Peter Safar's leadership, >60 such fellows served for ≥1 yr in research training at his facility. This resulted in hundreds of peer review publications and some 500 abstracts, with presentations at various national and international congresses. In 1988, Safar and Bircher published the textbook *Cardiopulmonary Cerebral Resuscitation*, which set the standard for the discipline and was translated into some 20 different languages (14).

In 1994, Peter Safar resigned from his directorship at IRRC. Peter Winter, chairman of the department of anesthesiology since 1979, appointed Patrick Kochanek, a pediatric critical care medicine faculty member at Children's Hospital and dedicated to brain research, as the new director of IRRC. Pat Kochanek immediately renamed IRRC to the Safar Center for Resuscitation Research. Peter Safar, together with Samuel Tisherman and others, continued their promising research to improve brain survival. Much of Peter's work focused on the use of hypothermia. Safar was one of a few key individuals involved in bringing renewed interest in hypothermia in the 1980s—spearheading the use of mild (rather than moderate) hypothermia in resuscitation from cardiopulmonary arrest. One of his former students, Fritz Sterz of Vienna, recently played an instrumental role in bringing this to clinical use by leading a successful European multiple center trial of this therapy, the results of which were published in the *New England Journal of Medicine* (15). More recently, Peter Safar and Sam Tisherman—along with a group of talented trainees—performed exciting studies on the use of profound hypothermia, induced by aortic flush of iced saline, to preserve and then resuscitate the heart and brain after cardiac arrest periods of 60–120 mins, previously unheard of. It was through Peter's collaboration with Ronald Bellamy in the Armed Forces, a noted authority on combat casualties in the Vietnam War (16), that this technique became an approach worthy of further investigation to study the military problem of combat victims bleeding to death in the battle field from injuries, which *per se* would be repairable and survivable if the victim could reach a surgical trauma facility in time for this intervention. Being able to keep heart, lungs, and brain alive for delayed resuscitation became known as "suspended animation." Some of the most important work on this exciting research has been recently published in *The Journal of Trauma* (17, 18) and *Critical Care Medicine* (19). Samuel Tisherman and his associates, who are continuing this promising research work, at the time of Peter Safar's death were planning to test the technique in civilian traumatology on victims arriving in hospital emergency departments in or close to cardiac arrest after extensive bleeding from various forms of trauma. Thus, Peter Safar brought this "science-fiction" technique to the doorstep of clinical trial but, unfortunately, was not given the opportunity himself to witness the expected first success of this modern approach to traumatic/hemorrhagic shock leading to cardiac arrest. To use Peter's own expression, these victims often represent unfortunate young individuals with "hearts and brains too good to die"—the target of his life's work in the field of reanimatology.

Critical Care Medicine and Related Fields

Clara Jean Ersoz was one of the earliest anesthesiology trainees in the critical care medicine program. She temporarily served as medical director of the general ICU at Presbyterian University Hospital in 1968, but she then moved to a prominent administrative position at St. Clair Hospital in southern Pittsburgh. Peter Safar took a sabbatical leave in academic year 1969–1970, joining Severinghaus and Comroe in research at their Cardiovascular Institute in San Francisco. During that time, he appointed Ake Grenvik as director of the ICU to later make him chief of the critical care medicine division in the department of anesthesiology. After returning to Pittsburgh, Peter initiated the second pediatric ICU in the nation at Children's Hospital. Stephan Kampschulte, a German anesthesiologist trained in Peter Safar's program, who had special interest in pediatrics, was appointed the first director of this ICU. He later returned to his native country after marrying another of our German critical care medicine fellows, anesthesiologist Marie Louise Lembke. Unfortunately, Stephan Kampschulte died of a massive stroke in 1994. During his early years in Pittsburgh, Peter Safar also initiated a respiratory therapy service with Bela Eross as the director.

In the 1970s, Peter Safar started a unique community emergency medical service, hiring unemployed African Americans and training them in basic resuscitation. The Freedom House Enterprise ambulance program was born and, most prominently, run by Nancy Caroline, an internist trained in Peter's critical care medicine program. She left in 1976 for Israel and became the medical director of Magen David Adom, the Israeli Red Cross. Nancy Caroline was an excellent writer and authored the first and widely spread Emergency Medical Services textbook, published in three editions (20). Dr. Caroline is frequently referred to as the "mother of Emergency Medical Services" in Israel.

Peter Safar was also heavily involved in ethical problems and, together with Ake Grenvik, served on a committee chaired by Pittsburgh Coroner Cyril Wecht to develop the first hospital guidelines in the nation on brain death evaluation and certification (21). This was of great importance when transplantation surgery flourished after recruitment to the University of Pittsburgh Medical Center of the widely known transplantation pioneer, Thomas Starzl. Furthermore, Safar and Grenvik, together with the ethicist and lawyer Alan Meisel, designed hospital guidelines, which also were among the very first in the nation, for foregoing life-sustaining therapy in futile cases (22–24).

International Involvement

Among Peter Safar's numerous international connections, his collaboration with Vladimir Negovsky's group in Moscow was unique. Already in 1937, Negovsky initiated a resuscitation research laboratory, studying the process of dying in search of new methods for "reanimation," such as intra-arterial administration of blood in lethal hemorrhagic shock. Peter visited Negovsky repeatedly, beginning in 1963, and Negovsky, in turn, visited Pittsburgh four times during their longstanding scientific friendship. After 50 yrs, Negovsky's Reanimatology Institute grew into the Laboratory of General Reanimatology of the USSR Academy of Medical Sciences as it moved from October Street near the Red Square to the outskirts of Moscow. This institution served as a model for Peter's establishment of his own IRRC. Incredibly, Dr. Negovsky preceded Peter Safar in death by 1 day.

During 15 yrs, from 1979 to 1994, most closely together with Norman Abramson, Peter conducted an international brain resuscitation clinical trial (BRCT), involving 20 medical centers in seven different countries. Promising drugs and techniques studied on animals in the IRRC laboratory were tested clinically (25–27). However, there was no obvious breakthrough, and Peter gradually turned to the greater potentials of hypothermia from simple mild hypothermia to the more complex profound hypothermia, as discussed above. Limitations on deferred consent, at the time, prevented Peter from carrying out the hypothermia trials in the United States.

Professional Honors

Peter Safar's curriculum vitae encompasses approximately 1,400 publications, including almost 400 peer-review articles, >600 abstracts, 20 books, and numerous book chapters and other publications such as invited reviews, guidelines, commentaries, and editorials. In 1968, during a Federation of the American Societies of Experimental Biology Meeting in Atlantic City, three "musketeers" with a common interest in management of the critically ill and injured patients, Max Harry Weil (internist/cardiologist), Peter Safar (anesthesiologist/intensivist), and William Shoemaker (trauma surgeon), jointly decided that it was time to start an association of professionals involved in intensive care. At a subsequent meeting in Los Angeles of 28 founding physicians of various specialties, the Society of Critical Care Medicine was established (28). Peter served as the Society's second president and initiated the Society of Critical Care Medicine journal, *Critical Care Medicine* (29). In the mid-1970s together with the late Rudolf Frey of Mainz, Germany, Peter started the Club of Mainz (30). This was later to become the World Association for Disaster and Emergency Medicine. During his presidency of the World Association for Disaster and Emergency Medicine, Peter initiated its journal, currently known as *Prehospital and Disaster Medicine*.

Over the years, Peter Safar received several honorary doctorate degrees from various universities, including the Johannes Gutenberg University of Mainz, Germany, in 1972; the University of Campinas in Brazil in 1996, and the Otto von Guericke University of Magdeburg in Germany in 1997. In 2003, he was to receive a Doctor Honoris Causa degree at Charles University in Prague of the Czech Republic, but his illness prevented him from receiving this honor in person. However, the University of Pittsburgh provided him with its Honorary Doctor of Science degree in February 2003, when he also served as the convocation speaker. In the mid-1970s, Peter Safar was an invited member of the White House Interagency Committee on Emergency Medical Services. In 1999, he received the Austrian Cross of Honor (first class) for Science and Art. The list of honors goes on and on. Three times he was nominated for the Nobel prize in medicine and physiology.

Elegance, Humanism, and Talent

Early during Peter Safar's incredible career in Pittsburgh, the expression about him was coined, "today anesthesia, tomor-

> *Despite the frenzy of 21st century medicine and the incredible purpose driving his important scientific missions, Peter accomplished all of his life's work with remarkable elegance.*

row the world." Indeed, Peter Safar became heavily involved in a large number of different areas throughout the world. Typical for Peter Safar, he was not only active in various medical societies but also in the World Federalist Association and in the International Physicians for the Prevention of Nuclear War. His passion for what he called peace medicine—doing good for mankind—was intimately linked to everything in his life, including his work on resuscitation. He believed that developments in the collective fields of acute medicine must be propagated universally. This was clearly reflected in this seminal work on the worldwide dissemination of cardiopulmonary resuscitation and was a theme to which he was always faithful during his illustrious career. "Simple, inexpensive, and effective," he would proudly say about a potential therapy that showed promise.

Despite the frenzy of 21st century medicine and the incredible purpose driving his important scientific missions, Peter accomplished all of his life's work with remarkable elegance, from sipping merlot for creativity at laboratory meetings, to making sure that visiting professors were treated like family members, and to religiously remembering everyone's birthday. While we were all trying to keep up with his science, he was writing letters to the current U.S. president, talking with the *Pittsburgh Post Gazette*, or working with physicians for social responsibility. One of the components of "Peter's Laws" was, "It is up to us to save the world" (1, p. 343). He led this quest by example.

Like most successful world leaders, Peter Safar was multitalented. He was a great family man and friend who was always available to listen to others and help them in any situation, such as escapees from post–World War II Europe seeking a new future in the United States. He was an athlete, mountaineer, excellent snow and water skier, and above all, a superb musician who loved to play classic Viennese compositions on his grand piano at home.

Peter Safar's Legacy

The future of all of Peter Safar's implementations looks extremely bright. The anesthesiology department is in the able hands of John Williams, occupying the endowed chair as the Peter and Eva Safar Professor in Anesthesiology and Critical Care Medicine. The Safar Center for Resuscitation Research continues its world prominence under Patrick Kochanek's leadership. Critical care medicine in 2000 was declared the first separate academic department in the United States, with Mitchell Fink as the founding chairman. The emergency medicine department, including the Center for Emergency Medicine, enjoys a worldwide reputation, with Paul Paris at the helm. A recent spin-off in the anesthesia department the Peter M. Winter Institute for Simulation, Education, and Research, which, with John Schaefer as its medical director, has become the largest and most active medical simulation center in the nation, building on Laerdal's modern simulation systems, which are a contemporary development of Resusci-Anne. Hundreds of other talented clinicians, scientists, and educators both in Pittsburgh and around the world will proudly carry on the Safar legacy, each feeling truly honored to have known him.

We feel enormously fortunate to have been able to witness and partake in the ingenuity and elegance of the life of Peter Safar. We will never forget the lessons he taught and the remarkable nuances that defined this special man—from the six rubber bands on his wrist to help him immediately organize the manuscripts and papers that constantly pelted him to the camera and tape recorder in his pocket ready to go to ensure that history would not be cheated. Although deeply saddened by the loss, we will move forward as colleagues and friends with renewed purpose—elevated to new heights and charged by the spark of genius.

A thousand thanks, Peter.

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Pioneering contributions of Peter Safar to intensive care and the founding of the Society of Critical Care Medicine

Max Harry Weil, MD, PhD, MACP, FCCM; William C. Shoemaker, MD, FACS, FCCM

During the Crimean War, Florence Nightingale, the parent of professional nursing, segregated the most severely injured soldiers and bedded them in close proximity to the nursing station. This perhaps represented the beginning of intensive care. During the poliomyelitis epidemics in Scandinavia of 1949 and 1952 and, subsequently, during the polio epidemic of 1948 and 1949 in Los Angeles, special respiratory units were organized for bag ventilation of patients with bulbar polio. Excepting postanesthesia recovery units first implemented by Dandy in 1923 at the Johns Hopkins Hospital, which evolved more fully during the Second World War, there were no intensive care units as we know them today until 1958 (1).

Almost concurrently, although with somewhat differing emphasis, Weil and Shubin at the University of Southern California School of Medicine and the Los Angeles County General Hospital and Safar at the Baltimore City Hospital developed the first physician-staffed medical and surgical units for management of patients with immediately life-threatening conditions (2, 3). The Los Angeles team was co-headed by two cardiologists, Weil and his life-long collaborator, the late Dr. Herbert Shubin, and Chief Surgeon Leonard Rosoff. It was initially named the Shock Ward because its initial emphasis was on acute circulatory failure. Peter Safar's unit was identified as an "intensive care" unit, with major emphasis on management of the airway and on breathing, following the tradition of Dandy (4). Both in the Los Angeles and in the Baltimore units, there was 24-hr/day, 7-day/wk physician commitment to the care of the most seriously ill and injured by a multidisciplinary team representing both medical and surgical specialties. The goal of both units was fuller commitment to lifesaving care for the most seriously ill and injured, with primary emphasis on breathing, circulation, neurologic recovery, and control of infection. Both were committed to clinical and laboratory research, although the focus of the research of the Eastern and the Western centers was quite different. The Los Angeles team focused on an understanding of mechanisms of acute life-threatening illnesses and injuries (5–7). Accordingly, it pioneered the development of monitoring and measuring devices. Equipment, including recorders, transducers, cuvettes, and thermocouples were taken from the physiology laboratory to the bedside. Central venous and arterial catheterization for pressure and cardiac output measurements by dye dilution techniques, measurements of central and peripheral body temperatures, detection and quantitation of life-threatening cardiac arrhythmias based on electrocardiographic heart rate and pulse rate, and respiratory frequency were implemented. The University of Southern California unit was a joint project of the departments of medicine and surgery and included isotopic methods for measurements of plasma and red cell volumes, especially for detection of hypovolemic shock. The "STAT Laboratory" concept was born in Los Angeles for rapid, "point of care" measurements of blood gases, electrolytes, and arterial blood lactate (8). As early as 1960, the University of Southern California unit began to implement, primitive, digital computer methods for data management and bedside display (9).

Peter Safar's unit maintained early emphasis on the airway and ventilation, in part an extension of the Safar-initiated priorities in 1957 of the A and B of cardiopulmonary resuscitation, including Peter's singular commitment to that of saving lives by demonstrating options for better management of the airway and breathing and for pharmacologic interventions (10, 11). Peter was an early proponent of titrated therapy. He and his associates maintained early emphasis on ventilation, cardiopulmonary resuscitation, and neurologic outcomes in addition to the other priorities of the modern anesthesiologist. The University of Southern California group emphasized circulation, including acute myocardial infarction, sepsis, and drug overdoses. In the years that followed, however, interest in circulation gained momentum in Pittsburgh and ventilation in Los Angeles.

In 1961, both units began the first fellowship programs in what emerged as critical care medicine. The initial leaders of the field came from these programs, and our graduates literally populated new centers all over the globe and constitute a new generation of critical care leaders.

In 1962, surgeon William Shoemaker began what became one of the first trauma units in the United States at the Cook County Hospital in Chicago (12). Shoemaker had been trained in surgical physiology at the Peter Bent Hospital in Boston by the famed Dr. Francis Moore and in biochemistry by Baird Hastings, the Harvard University giant of the field. In that setting, Shoemaker's interest included hemorrhagic shock and its complications and the hemodynamic and metabolic consequences of injury (13).

It was at a meeting of the Federated Societies in Atlantic City and during a casual walk on the famed boardwalk that Safar, Shoemaker, and Weil first shared concepts and aspirations on the care of patients with life-threatening conditions. Cardiologist/physiologist Weil, anesthesiologist/resuscitation-leader Safar, and surgeon/physiologist Shoemaker found a

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commonality of concepts and goals. Peter was already well armed and, in fact, experienced in identifying the need for a more appropriate system, beginning with out-of-hospital emergency care. He promoted triage and stabilization of patients at the site, competent management during prehospital transport, preparedness for direct admission to the hospital emergency area, and orderly passage through preanesthesia, operation, and postoperative recovery. To Peter, the rational extension of this system was that of intensive postoperative care in either or both postoperative recovery and intensive care units. Peter also had a keen appreciation for the diversity of disease states that were not exclusively in the domain of the anesthesiologist, including drowning, life-threatening bronchoconstriction, coma and vegetative states, and out-of-hospital cardiopulmonary resuscitation. Weil and Shubin both had a background in cardiorespiratory physiology. Weil had his residency and fellowship training at the University of Minnesota in the laboratories of the famed physiologist Maurice Visscher and infectious disease expert Wesley Spink. At the Mayo Clinic, Weil was under the tutelage of clinical physiologists Earl Wood and Ward Fowler and the famed cardiologist Howard Burchell. On the boardwalk in Atlantic City, the appropriateness of the multidisciplinary commitment to patient care by three academic doctors from diverse specialties became a bond. This multidisciplinary commitment to acute care emphasized the patient but also recognized the huge implications for acute care education and research.

Like comrades in arms, Safar, Shoemaker, and Weil maintained continuing dialog over the ensuing months, and their discussions culminated in meetings initially in Los Angeles in February 1970 in conjunction with the Eighth Annual Course on Critical Care Medicine and Shock, sponsored by the University of Southern California School of Medicine and its division of critical care medicine chaired by Weil. In July of 1970, the three initiators and their associates expanded to a group of 28 invited American medical leaders from diverse specialties. The intent was to propose an organization that became the Society of Critical Care Medicine. At the Ninth Annual Course on Critical Care Medicine and Shock in Los Angeles in February and later that year in May of 1971 at a course directed by Peter and the Department of Anesthesiology of the University of Pittsburgh, the Society was formally inaugurated with 100 members. Dr. Aki Grenvik, Peter's student and colleague, was a major contributor to the initial success of Society of Critical Care Medicine as chairman of the membership committee. Weil was elected as the first president and began the tradition of what became annual presidential addresses (14). Safar was the second president and Shoemaker was the third president. In January of 1973, strongly supported by Safar and Weil, Shoemaker became the founding editor of *Critical Care Medicine*, now the leading journal in the field, worldwide, in critical and intensive care.

We defer to our colleagues who contributed to this special issue of *Critical Care Medicine* to cite the remarkable achievements of Peter Safar, our friend, colleague, and leader. They will appropriately speak about Peter's extraordinary breadth of interest and involvement. The innovative and pioneering contributions of Peter started with resuscitation. The A, B, and subsequently, A, B, and C of cardiopulmonary resuscitation were Peter's. They will speak of the extraordinary humanism of Peter that complemented and reinforced his contributions to education, science, and practice. Peter Safar's home discipline was clinical anesthesia and its day-to-day practice. However, it was always in the context of saving lives. His involvement in prehospital emergency care of patients extended all the way from the site of intake to discharge from intensive care. He helped pioneer disaster care. His humanism was exemplary and courageous. He would risk his reputation to foster even politically unpopular proposals that would save lives—always respecting lives, but also the need for gently guiding patients out of life when there was no longer capability to maintain meaningful life. A workaholic by his own description, he was a beloved mentor and an academic parent to so many, including medical students, residents, fellows, and professional nurses. To his colleagues, he was a compassionate friend, a collaborator, and respectful combatant and, ultimately, a conciliatory compromiser.

Peter had visualized a comprehensive system of acute care that, as cited above, would start at the prehospital site of injury, illness, or disaster, provide for initial stabilization before transport and entry into the hospital, triage and emergency management on arrival, orderly transfer to the operating room or intensive care unit, and all of these under the umbrella of "resuscitation" or the French model of "reanimation." Stimulated by the extraordinary respect he had for the contributions of his Russian colleague and friend, Professor Negovsky, Peter regarded himself as a resuscitation physician (15, 16). Peter most persuasively sought to combine emergency medicine, intensive care, and disaster and rescue medicine as one discipline. The name critical care medicine, synonymous with intensive care medicine, was in part from the title of a 1966 monograph authored by Dr. Stephen Ayres, entitled "The Care of the Critically Ill" (17), and from the name of the 42-bed Center for the Critically Ill, which was the 1967 successor unit of the Los Angeles University of Southern California Shock Ward (18). Peter, during the years that followed, remained committed to the ultimate unification of emergency, disaster, and critical care medicine under a single multidisciplinary specialty umbrella. However, critical care medicine became a subspecialty, and emergency medicine ultimately became a separate primary specialty (19).

Peter Safar's autographic memoir speaks beautifully of the unique achievements of this great man (14). Of the two remaining of the trio of critical care initiators, we were blessed by admiration and professional friendships that existed among the three of us during our professional lifetimes. We shared destinies for >35 yrs. As we mourn Peter's passing, we perceive it as a painful and personal loss. However, his wondrous hold on life, always moving forward against odds and in so many spheres, fortified us all. The extraordinary qualities of this giant are best described in his own words: "The impossible is simply a greater challenge." One of us (M. H. Weil) had the privilege of maintaining close contact with him in the last year when, with the compassionate closeness and support of his wife, Eva, overwhelming cancer and infection would not dampen Peter's spirit. His extraordinary commitment to life and unrelenting spirit to move forward against impossible physical odds of pain and disability were with vigor, decorum, and even charm and, most remarkably, without even a complaint. We will do well to commit ourselves to keep our eye on the horizon projected by Peter, for it extends beyond our individual identities as physicians and even beyond the Society which he served so well.

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Memorial Service Honoring Dr. Peter Safar, Heinz Chapel, Pittsburgh, PA, October 29, 2003: Remarks of Chancellor Mark A. Nordenberg

Good afternoon. Let me welcome each of you as we gather to remember the life of Dr. Peter Safar and to honor his memory. On behalf of the entire university community, I want to extend an especially warm welcome to Eva Safar, to Philip Safar, and to Paul Safar. We are pleased to be with you today, we are grateful to you for sharing your husband and father with us for so many years, and we recognize that your encouragement and support were essential to all of Peter's many important accomplishments.

Over the course of its proud, 216-yr history, this university has been the home to many high-achieving professionals who also were wonderful people. However, few have had the kind of impact, here and at a distance, that Peter Safar did.

Peter was not just a pioneer within his discipline. Instead, he could be viewed as the creator of several disciplines. And his work within them not only enriched lives, it saved them, and in very large numbers. As distinguished and influential as Peter was within his field, he was never confined to it. Instead, his curiosity was almost boundless, and he seemed interested in virtually any cause that might improve the human condition. And Peter's interest in the human condition was not abstract but was, instead, reflected in his everyday dealings with others. Peter was not just a friendly and courteous person, he took kindness and grace to new levels—or, perhaps, it was back to old levels. Certainly, in this modern and, too often, impersonal world, his courtly demeanor stood out, almost as some type of personal art form.

I always felt privileged to be a part of a university that included Peter Safar. And I always felt blessed that he considered me to be a friend. And I always felt lucky that I had the chance to benefit from his thinking on a range of important issues.

More than two centuries ago, Voltaire wrote: "I know of no great men except those who have rendered great services to the human race." Certainly, Peter met that test, and he did it from within our midst. But for so many of us, Peter also was a great man because of the many smaller services he rendered to us individually, as his colleagues and friends.

Peter was a great and gracious person, and he will be missed. We all are very lucky to have known him, and we also are fortunate to have the enduring benefit of his unique and inspiring example.

From the University of Pittsburgh School of Medicine, Pittsburgh, PA.

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Memorial Service Honoring Dr. Peter Safar, Heinz Chapel, Pittsburgh, PA, October 29, 2003: Remarks of Senior Vice Chancellor Arthur S. Levine, MD

Dr. Peter Safar once told an interviewer that our first calling is to use the gifts we are given and to make the world a better place. It seems to me that Peter was someone who followed his own advice quite well. It's no doubt that the gifts he displayed as a physician, an educator, a researcher, and a gentleman were remarkable, but all the more remarkable was what he did with those gifts, especially to aid people in their most fragile and vulnerable moments of life.

Dr. Safar's revolutionary body of work in resuscitation, emergency medicine, and critical care made him an icon in the world of medicine. His influence was most certainly felt here at the University of Pittsburgh, which had the wonderfully good fortune to be his scientific home for 42 yrs. He was, in fact, one of the key figures who helped launch the School of Medicine to the prominence it now enjoys. Quite literally, he helped put us on the map, but his influence on the global scale cannot be discounted.

The innovations he developed have changed the face of medicine and the way it is practiced around the world, especially critical care medicine, which, until Dr. Safar came along, was not considered the specialty it is today. The multidisciplinary fellowship training program in critical care medicine that he established here at Pitt has trained hundreds of intensivists—doctors who specialize in treating critically ill patients in intensive care units—and because of our leading role in this field, the School of Medicine last year became the first in the nation to establish a department of critical care medicine.

Dr. Safar's legacy will live on through the important work of the Safar Center for Resuscitation Research, which so appropriately bears his name, as do the new annual Safar Symposium and the long-standing Peter and Eva Safar Annual Lectureship in Medical Sciences and Humanities. His legacy will also live on in the minds and hearts of those who knew him and his charm, his ready smile, his diligence, his dedication, and his enthusiasm. In a very real way, his legacy will even live on through the millions of people who never knew him but whose lives he touched because of the extraordinary medical accomplishments he left behind.

I would like to reflect briefly on just one of those accomplishments: cardiopulmonary resuscitation. As one of the pioneers of this life-saving technique, Dr. Safar pushed for acceptance of CPR in the medical community. Now, many years later, it is widely recognized as an essential response to life-threatening cardiopulmonary emergencies. As such, it is taught to millions of people each year and is credited with saving thousands of lives.

As anyone in medicine will tell you, being able to save even a single life is one of the most rewarding experiences anyone can imagine. However, the vast majority of cardiac arrests take place outside of hospitals—in people's homes or in public places with no trained medical personnel around. Peter labored diligently and passionately to put CPR into the hands of ordinary people by training them how to use it anywhere, anytime, so they might be able to sustain patients through the critically important minutes until medical care arrives, and sometimes to even save a person's life.

It happens all the time. Three buddies were playing golf at a country club in Bulltown, PA, one day when one of them suddenly collapsed on the 13th hole; the other two performed CPR until help arrived. In Sheboygan, WI, a young man who knew CPR likewise helped save his 51-yr-old father who went into cardiac arrest while cutting grass at home. And just the other day here in Pittsburgh, an everyday hero who is certified in CPR resuscitated an elderly man who collapsed on a Port Authority bus.

Dr. Peter Safar empowered people to make a real difference in the lives of others, just as he himself made a difference. And so, every time someone new learns or uses CPR, his legacy will live on as well. We come here today to celebrate that legacy, which will be with us for a long, long time. There's no doubt that Peter Safar used his gifts well to make the world a better place. He once said quite simply: "I made use of the opportunities that life offered to do some good." And for that, Peter, we thank you.

From Health Sciences, School of Medicine, University of Pittsburgh School of Medicine, Pittsburgh, PA.

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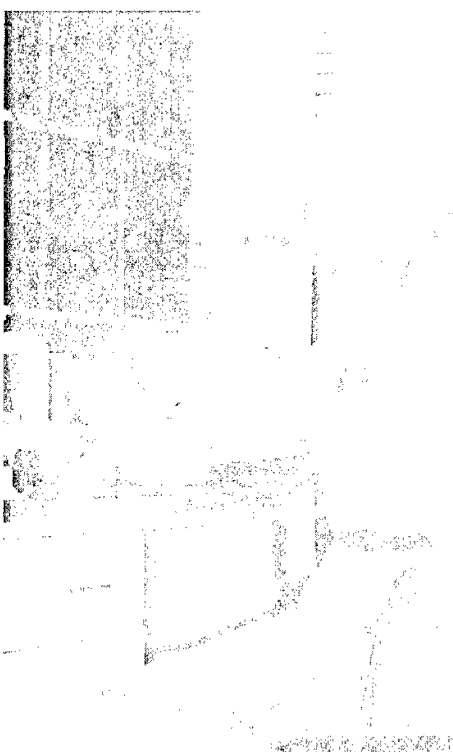
Quotes From Colleagues and Friends in Celebration of the Incredible Life of Peter J. Safar, MD



Dr. Peter Safar in action at the International Resuscitation Research Center during the heyday of the Brain Resuscitation Clinical Trials (BRCT) conducted out of the center, circa 1985.

Peter Safar and I have been friends for nearly forty years. When I was still a wet-behind-the-ears anesthesiologist/scientist and he was the founder of his third anesthesiology department, he and I had research interests in common having to do with pulmonary pathophysiology. We also had first names and a Viennese background in common. To my intense astonishment, he treated me as an equal and a colleague. Ever since, I have observed his career with awe, affection, and respect.

In addition to being the founder of the department, which I was privileged to chair, Peter was a hugely productive investigator whose work had impact far beyond anesthesiology. His development of resuscitation made a profound impact on medicine as a whole and on the lay public as it has saved countless lives. Not content with scientific impact, Peter went on to become, perhaps uniquely, a creator of fields and professions. He was an instrumental leader in the development of the fields of critical care medicine, respiratory therapy, emergency medicine, disaster medicine, and resuscitation medicine, helping found societies and journals that came to define these now independent disciplines. For his numerous and important contributions to the world he was three times nominated for the Nobel Prize.

He accomplished all of this with endless, intense hard work and with charm and charisma, often over the doubts and impediments of bureaucrats who could not understand his vision. He was also a world citizen and a peace advocate who befriended and encouraged everyone with whom he came in contact, from young children to academic physicians in the Soviet Union at the height of the Cold War. Of the many things he taught me, the most memorable was, "It is up to us to save the world."

In later years he was, for me, the ideal "former chairman." He was always available to help and advise when sought and never interfered unless asked. Clearly, one of my responsibilities as chairman was to champion, aid, and abet his activities and to help to promote his many triumphs. It was a privilege beyond measure. I, and all who had the honor of knowing him, miss him deeply.

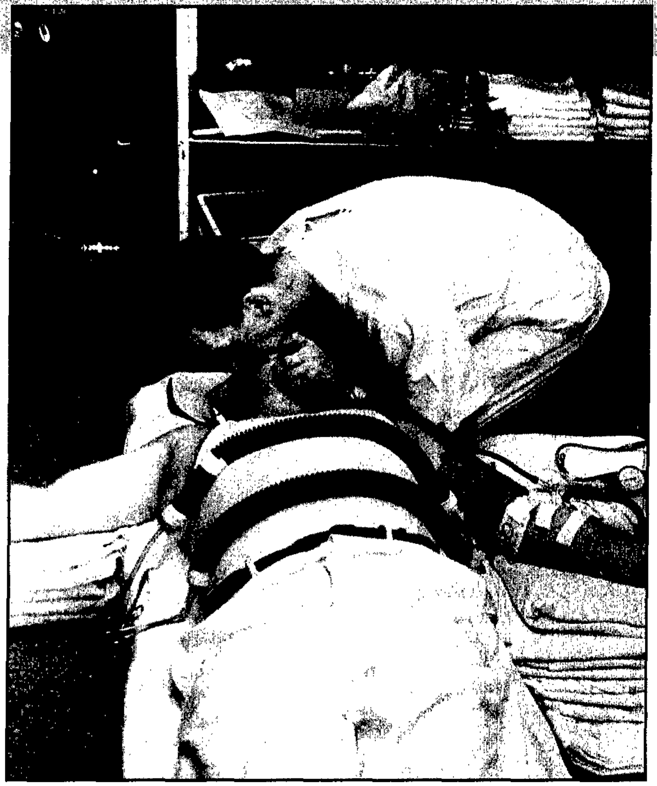
Peter M. Winter, MD
Professor and Chairman, Emeritus
Department of Anesthesiology
University of Pittsburgh

Historic photos from the birth of CPR, circa 1957. Baltimore City Hospital was the site of remarkable human studies in which volunteers were administered neuromuscular blockade and the efficacy of mouth-to-mouth resuscitation was documented.

[right] Dr. Safar and volunteer Dr. Felix Steichen document the head-tilt jaw-thrust and mouth-to-mouth resuscitation.

[below] Dr. Safar squats behind the anesthesiology machine and describes this new method to the lay public.

[below right] One-on-one demonstration of this method to a boy scout.



The wonder of Peter Safar's professional life is not in the remarkable accomplishments recorded in his CV, and they were too numerous to recount, nor even in the fact that during his life he affected so many other lives. Certainly, Peter's untiring efforts affected survival and quality of life for patients throughout the world and are accomplishment enough for history to judge a man great. And one could look at the number of colleagues with whom he inspired and the impressive numbers of grants they have obtained or papers they have published. Again, accomplishment enough for any great man.

But to my thinking these are not the only, nor indeed the most important, metrics by which to measure the greatness of this man. Peter's truly unique accomplishment is the emotional connection he inspired among his friends (as he would call them) — not only toward himself, but toward each other. These "friends of Peter" have grown into a vast network of colleagues, all committed to continuing inquiry and research inspired by Peter's visions.

Peter's immortality is assured. For those of us fortunate enough to have known him will continue in his footsteps and will continue to affect others, who in turn will affect others. And this cycle will continue as long as man's battle against premature death continues. And so will continue the memory and impact of a great man.

Norman S. Abramson, MD for the BRCT Investigators

As one of the true clinician-scientists, Peter challenged poorly reasoned and substantiated dogma. His work literally saved tens of thousands of productive lives. He led by example, teaching us the lessons of diligence and tenacity. Peter was a consummate artist in everything he did, seeing clearly how things ought to be. Peter not only developed the techniques for resuscitation, but laid the intellectual foundations for their study and improvement.

Nicholas G. Bircher, MD
Associate Professor
Department of Anesthesiology
University of Pittsburgh

I was privileged to observe him enlighten, educate, and kindle the true spirit of humanitarianism in fellow professionals and laypersons alike. Simply stated, his unique gift provided medical professionals and laypersons worldwide with a basic sense of confidence and competence that enabled them to come forward, kneel down, and use their hands and breath to save a human life. Could there ever be anything more beautiful and precious?

Allan Braslow, PhD
Education Researcher & Developer
President, Braslow & Associates
Greenwich, CT

Dr. Peter Safar (front row, 3rd from left) and his Anesthesiology faculty at the Baltimore City Hospital, circa 1959.

For more than four decades, the U.S. Army Medical Department has had a long history of support for the work of Dr. Peter Safar. We have been partners from the early days of his groundbreaking work in the development of cardiopulmonary (cerebral) resuscitation and the establishment of the first intensive care units to his more recent creation of a resuscitation research center and his work in controlled hypothermia for cerebral protection following hemorrhagic shock.

The Army owes Peter Safar a great debt of gratitude for all of his work to radically improve the care and survival for all severely injured people.

His dedication, energy, vision and compassion will continue to be an inspiration.

COL Dean E. Calcagni, MC
Deputy Director
Telemedicine and Advanced Technology Research Center
U.S. Army Medical Research and Materiel Command

During a cocktail party that was given for me by the medical school of the University of Pittsburgh during the course of one of my recruitment visits in the spring of 1972, Peter Safar, who was then the chairman of the Department of Anesthesiology, walked up to me and said, "I want you to come. If you are willing to deal with their minds, I will be happy to try keeping them alive." Since I am Hungarian by origin, his Viennese accent and mine was the source of some amusement to those who witnessed our conversations.

Thomas Detre, MD
Medical Director
International Programs
University of Pittsburgh Medical Center
Distinguished Service Professor of Health Sciences
University of Pittsburgh

Dr. Peter Safar (standing at left taking photograph) at the Negovsky Institute in Moscow in 1963. Political barriers were unable to prevent Dr. Safar from carrying out his mission in the worldwide dissemination of CPR; not a trivial feat in light of the state of the world in 1963. Dr. Safar had great respect for the innovative work of Dr. Vladimir Negovsky and his resuscitation center in Moscow. Dr. Negovsky is the third to the right of Dr. Safar.

Just before I knew he was sick, I asked him to join the proposed Association for Humanitarian Medicine, but his open mind and universal spirit responded saying, "Is not all medicine humanitarian?" "Of course," I said, in disagreement, "while all medical intervention to reduce suffering is in essence humanitarian, Humanitarian Medicine goes far beyond." He then magnanimously revised his initial reaction, saying, "You are right, count me in." You are in, Peter, the humanitarian doctor and the scientist without borders.

S. William A. Gunn, MD
With Peter Safar and friends, a cofounder of the World Association for Disaster and Emergency Medicine
Founder, International Association for Humanitarian Medicine

"Humanitarian Medicine – as defined in The Dictionary of Disaster Medicine and Humanitarian Action, 2nd edition: While all medical intervention to reduce a person's sickness and suffering is in essence humanitarian, Humanitarian Medicine goes beyond the usual therapeutic act and promotes, provides, teaches, supports, and delivers people's health as a human right, in conformity with the ethics of Hippocratic teaching, the principles of the World Health Organization, the Charter of the United Nations, the Universal Declaration of Human Rights, the Red Cross Conventions, and other covenants and practices that ensure the most humane and best possible level of care, without any discrimination or consideration of material gain."

On May 21, 1997, Dr. Peter Safar, originally of Austria, received the Golden Rathausmann Award (a miniature of the statue atop the Rathaus (City Hall), and the equivalent of the "key to the city") from the mayor of Vienna. We were honored to be included among the invited guests and thus had the opportunity to witness this expression of the country's pride in one of its native sons.

Later that evening, we met Peter at a Weinstube in Vienna for a quiet dinner among old friends. We had a copy of that day's city newspaper, Der Standard, which featured a front-page picture of the award ceremony along with a description of Peter's illustrious career. A waiter took a photograph of the three of us sitting together that evening, Peter in the middle holding a copy of the newspaper under his chin - our "proof of life" picture. Copies of that photo sit in our offices today as a cherished memento of that treasured event.

Christopher M. Grande, MD, MPH
Executive Director, International Trauma Anesthesia and Critical Care Society (ITACCS)
Anesthesiologist and Intensivist

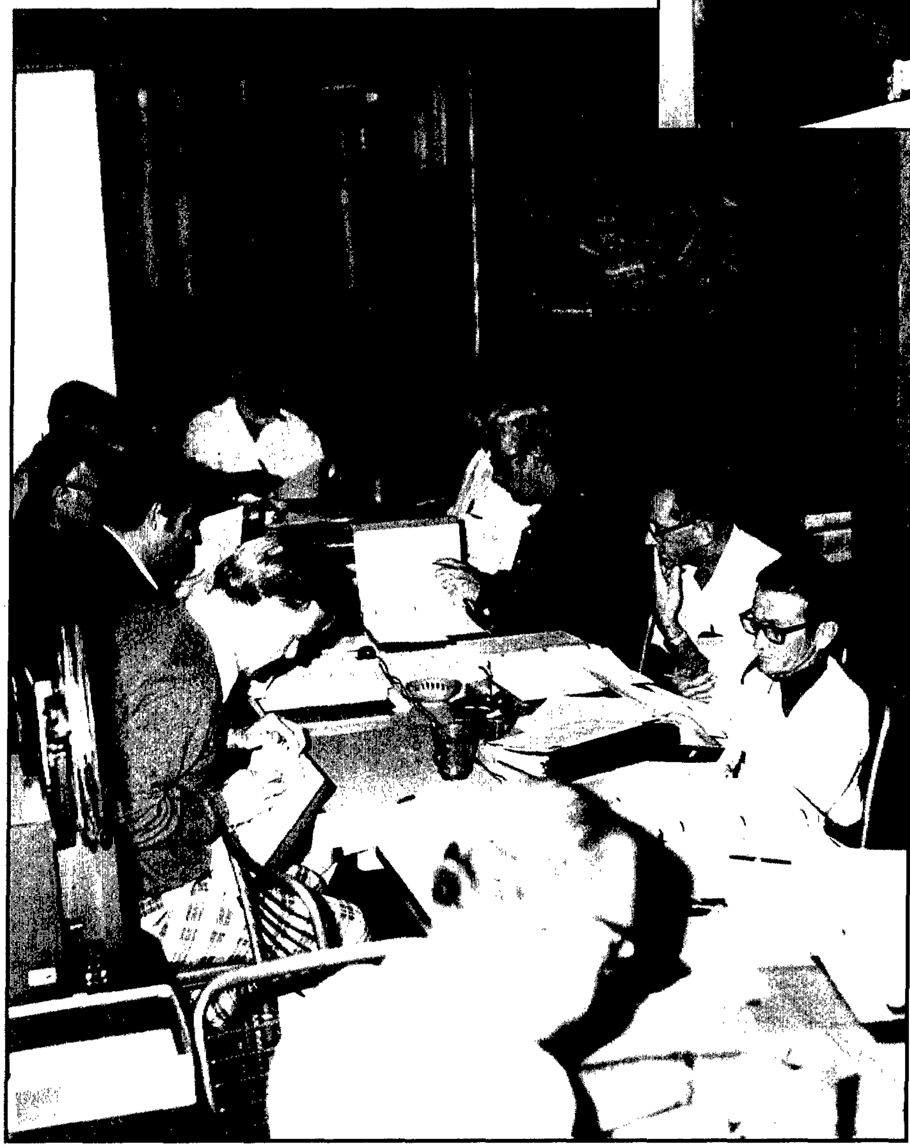
Walter Mauritz, MD, PhD
Director, International Trauma Anesthesia and Critical Care Society (ITACCS)
Chair
Department of Anesthesiology
Lorenz Bohler Trauma Center
Vienna, Austria

Dr. Peter Safar (3rd row, 1st on left) and the participants in the Freedom House Ambulance project in Pittsburgh in 1975. This project was instrumental to the development of Emergency Medical Services (EMS) in Pittsburgh. Project leader Dr. Nancy Caroline (1st row, center) was an early fellow of Dr. Safar's who went on to become the Mother of EMS and Director of the Red Cross in Israel.

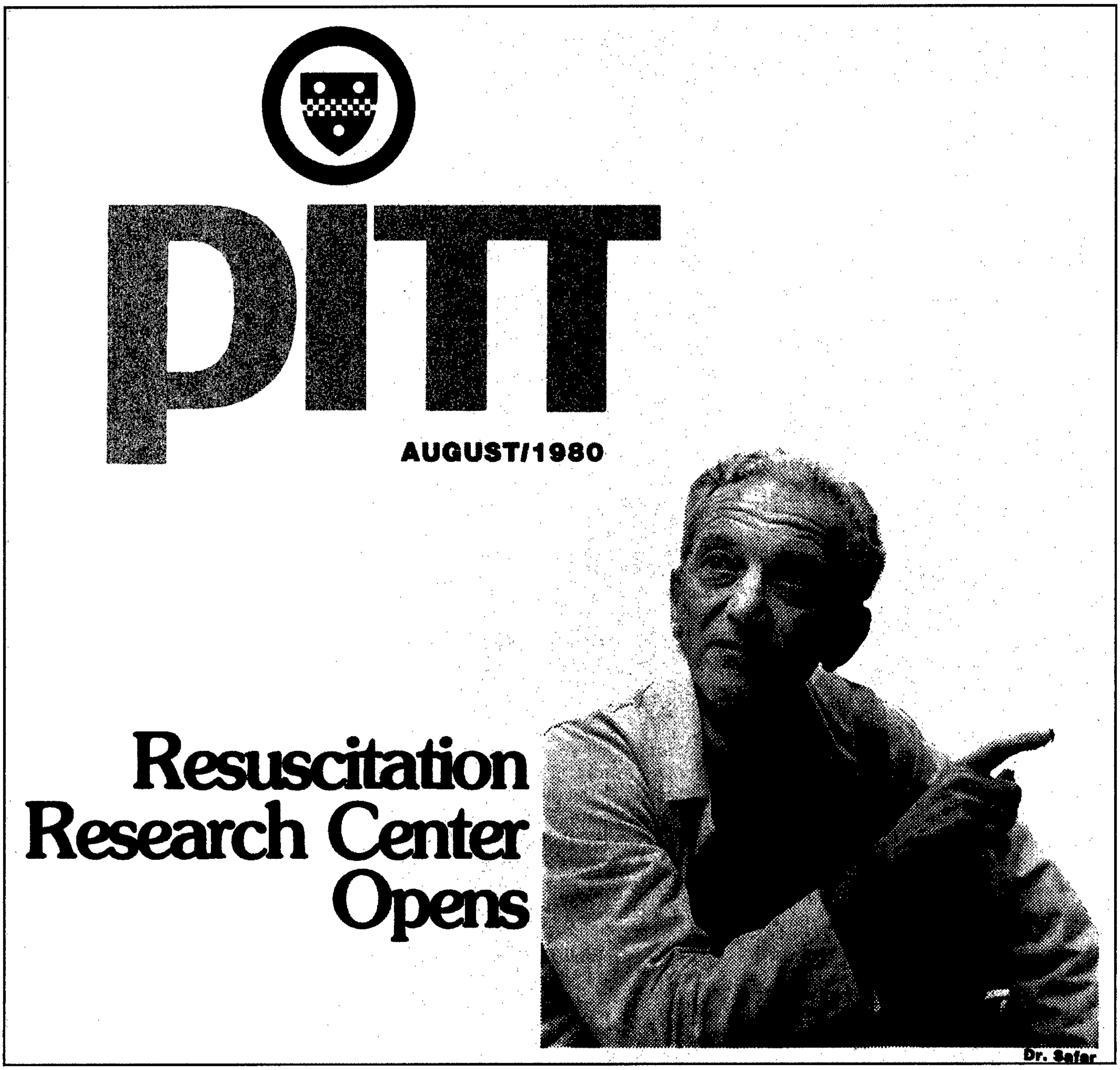
I was traveling back from an out of town meeting on the same plane with Dr. Safar in the Fall of 2002. He had known we would be on the same flight, and because he was in between chemotherapy sessions and had recently undergone a major surgery, he asked if I could "look out for him." After an uneventful flight, we gathered our luggage from baggage claim and I prepared to accompany him to the parking lot. We were both parked in Extended Parking, more than a mile from the terminal. Dr. Safar, pulling his luggage with one arm and carrying a stack of papers under the other, began heading towards the corridor leading to the long walkway that extends all the way to the parking area. I pointed out to him that he was heading in the wrong direction. If we wanted to catch the shuttle bus to the parking area, we had to take only a short walk in the opposite direction. He paused only long enough to look down at my knees and ask, "Is there something wrong with your legs?" I had to sprint a few yards to catch up with him!

Robert Hickey, MD
Children's Hospital of Pittsburgh
Division of Pediatric Emergency Medicine
Pittsburgh, PA 15213

CPR pioneer Dr. Peter Safar (left) and Laerdal Medical founder Mr. Asmund Laerdal in 1980. Asmund Laerdal, with input from Drs. Bjorn Lind and Peter Safar, spearheaded the development of CPR mannequin Resusci-Anne. Peter Safar often said that business discussions related to the development of Resusci-Anne in the early 1960s were made with a hand shake rather than a contract. The Safar and Laerdal legacies will forever be intertwined.



Dr. Peter Safar (2nd from right on right side of table) at the historic meeting of the Wolf Creek Conference in 1975. Dr. Joseph Redding, another pioneer in the field of resuscitation medicine, is seated to the right of Dr. Safar. Drs. Max Harry Weil and James Elam were among the esteemed faculty at this meeting in the origins of the development of resuscitation guidelines.



Dr. Peter Safar in 1980 at opening of the Resuscitation Research Center (now Safar Center for Resuscitation Research) at the University of Pittsburgh.

Peter Safar was dedicated to the values of human life and human rights in the most thoughtful and passionate ways. His own life was fulfilled by his service to these values in medicine, in the academy, and in the World Federalist Movement. He was a World Federalist through and through, intensely committed to promoting the global rule of law to achieve peace in the world. He was not a pacifist: he knew that there was real evil in the world that had to be fought steadfastly. But he always had the cause of peace and justice in his mind. Peter Safar was a man of global vision and of service in the cause of humanity.

Burkart Holzner, PhD
Distinguished Service Professor
International Studies Emeritus
University of Pittsburgh

Our time in life is brief. Most accomplish little that benefits those to come. Everyone should leave a legacy, no matter how small. Some, however, like Peter Safar have far exceeded this minimum. Peter has left something that benefits all humanity. His work on respiratory and brain resuscitation has earned him this neverending legacy. Combined with cardiac resuscitation as CPR, this work has become widely accepted and applied. The name of Peter Safar may, in the recesses of time, be lost in the association with his work, but the work will remain and continue without a knowing end. We owe much to Peter, his associates, and all those who continue to spread and educate from his achievements. On a personal note, my memory of Peter will always revolve around his accent and his "very large" briefcase.

James R. Jude, MD
Coral Gables, Florida

[left] The international scope of Dr. Peter Safar's work was truly remarkable. In addition to the aforementioned travel and collaboration with the Negovsky group in Moscow, Dr. Safar served as the President of the World Association of Disaster and Emergency Medicine from 1981-85 where he met Pope John Paul II.

[right] Dr. Safar with President and First Lady Jimmy and Rosalyn Carter at the Carter Foundation.

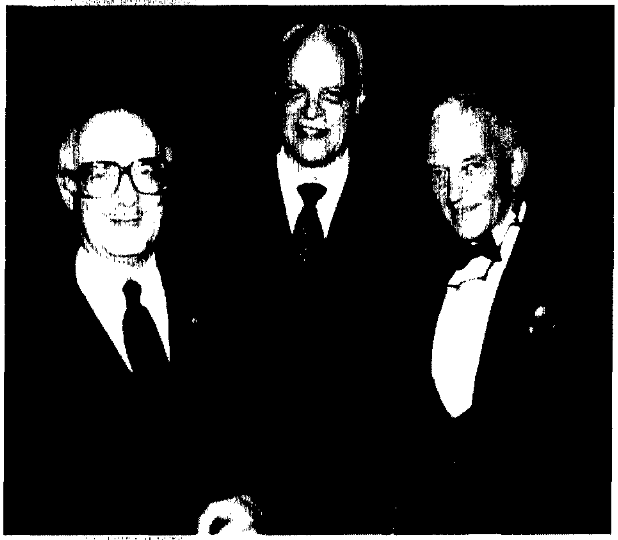
[below] Dr. Safar accepting the Austrian Cross of Honor (First Class) for Science and Art from Harald Miltner (Consul General of the Republic of Austria) on March 19, 1999. This is Austria's highest civilian honor.

I went to the University of Pittsburgh Medical School because Peter Safar was there, intending to meet him, which I did. He was well-known in ambulance driver circles in which I was active before medical school.

I chose anesthesia and critical care because he was an enormously positive role model and counsel.
I study the brain because of his influence early in my career.
I try to pass on to medical students and residents the same enthusiasm and dedication he showed me.

Although he is missed now, his impact will continue for generations.

W. Andrew Kofke, MD, MBA, FCCM
Professor, Anesthesia and Neurosurgery
Director of Neuroanesthesia
University of Pennsylvania



Drs. Max Harry Weil (left), William Shoemaker (center), and Peter Safar (right), the three founding fathers of the field of Critical Care Medicine in the United States and the Society of Critical Care Medicine, circa 1985.

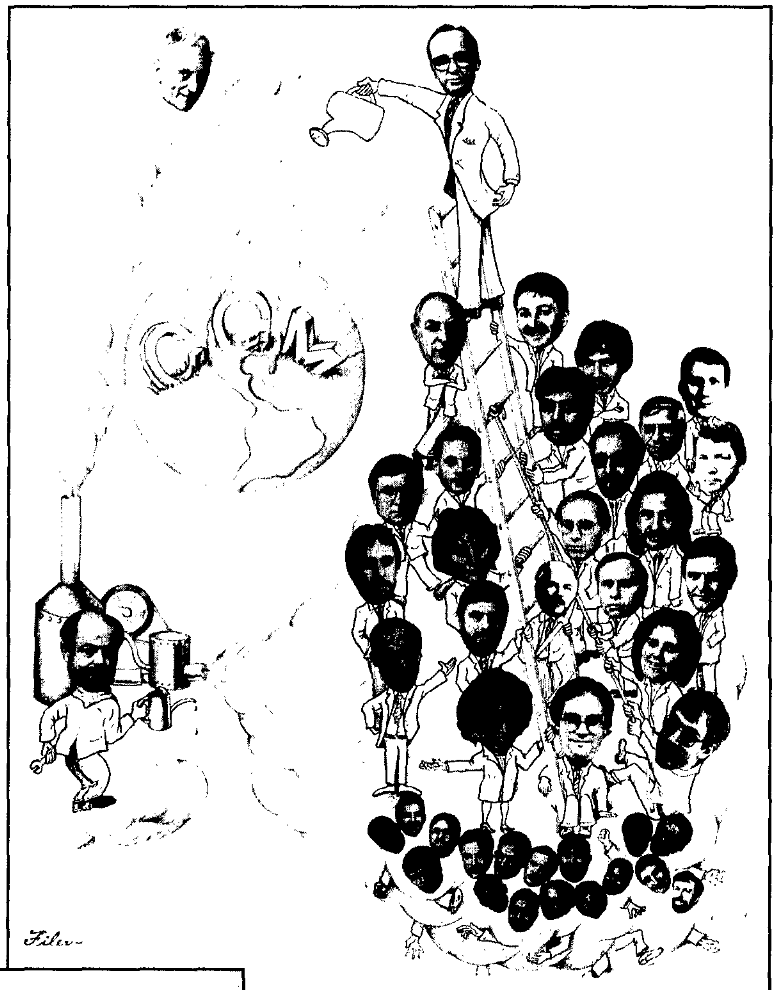
In 1982 I was an undergraduate student in college and curious about how resuscitation research was performed on dying patients. I wrote letters of inquiry and sent a copy of my senior thesis (Hypothermic resuscitation) to a number of investigators including Dr. Safar, whose name I found in a popular press magazine. Dr. Safar was the only person to write back and I was surprised when he invited me to Pittsburgh to see how to "properly conduct" research. I took a bus from New Jersey to Pittsburgh a couple of weeks later and thanks to the support and guidance from his assistants, Fran Mistrick and Nancy Moran, I was able to stay in student housing for a week while Dr. Safar gave me a grand tour of the International Resuscitation Research Center (IRRC). Upon completion of my visit, I expressed my desire to continue work in the field of medicine and Dr. Safar invited me to return as a "premedical research fellow" at the IRRC. His only condition was that I maintain his philosophy that research must be shared with others and never be performed in secrecy. He encouraged me to be open to ideas from the younger generation and promote their enthusiasm and curiosity. He provided me with these wonderful words of wisdom while we sat at a back table and drank plum wine in the Chinese restaurant around the corner from the Safar Center for Resuscitation Research (formerly IRRC).

Laurence Katz, MD
Associate Professor
Department of Emergency Medicine
University of North Carolina at Chapel Hill

The American Society of Anesthesiologists is saddened at the passing of Dr. Peter Safar. We have lost a giant. Dr Safar's commitment to the care and safety of patients will be missed. Yet, each day, patients continue to benefit from his commitment to them. His legacy lives on.

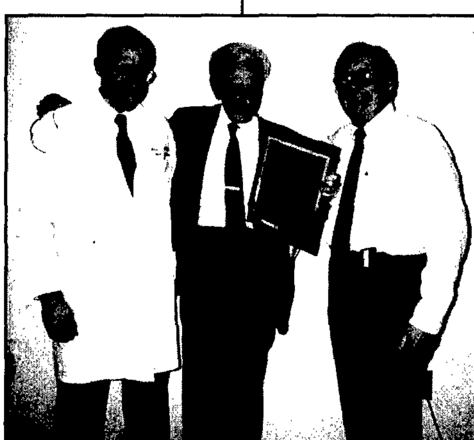
Roger W. Litwiller, MD
President, The American Society of Anesthesiologists

Cartoon (circa 1989) of the Critical Care Medicine (CCM) Division within the Department of Anesthesiology and CCM that Dr. Peter Safar spawned at the University of Pittsburgh. The Anesthesiology and CCM departments are now separate and currently comprised of 133 and 47 faculty, respectively. Dr. Safar is in the upper left in the clouds, Dr. Ake Grenvik is watering the CCM Division, while Dr. Peter Winter (left) as department chairman is oiling the furnace that was the Department of Anesthesiology and CCM.

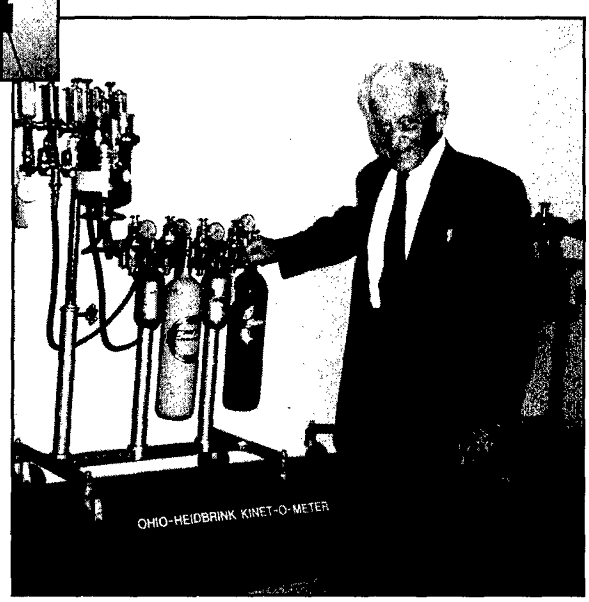


When I had the privilege of meeting Dr. Peter J. Safar a few years ago, I was immediately fascinated by his joie de vivre. His was an inquisitive, energetic mind that produced major innovations in the critical areas of cardiopulmonary and cerebral resuscitation. Yet he understood with every fiber of his being that medicine is a unique and vital mix of art and science. I was impressed by his love of the humanities, especially music and literature. His eyes would sparkle even more than usual when he discussed the musical contributions of Gustav Mahler and Anton Bruckner! Peter Safar touched people in a very special way, whether as a teacher, scientist, humanist, or friend, and he and his infectious passion for life and for excellence will be profoundly missed.

Kathryn E. McGoldrick, MD
President, Wood Library-Museum of Anesthesiology



Dr. Peter Safar received the Lifetime Achievement Award for SCCM surrounded by former Critical Care Medicine Chief, Dr. James Snyder, and Distinguished Service Professor of Critical Care Medicine, Dr. Ake Grenvik, at the University of Pittsburgh, circa 2002.



Dr. Peter Safar at the Wood Library-Museum on the occasion of the entry of his autobiography into that prestigious library. In addition to his incredible accomplishments in Critical Care Medicine and Emergency Medical Services, Dr. Safar's core specialty was Anesthesiology, and he is considered one of the foremost figures in the history of that field.

Medicine has been blessed by the presence and contributions of this scholarly, yet down to earth, physician in the fields of anesthesia, critical care medicine, and especially resuscitation. Peter, the "Father of Modern CPR," accomplished over his lifetime what few have ever done. I will always remember the friendly smile, the twinkle in his eye, and his compassion and service for all mankind. He was an outstanding teacher, scholar, writer, researcher, prognosticator, and a true friend. I will greatly miss his wit, humor, and most of all the man, a man for all ages and a "giant" amongst us all.

William H. Montgomery, MD
Founder and Immediate Past President, Citizen CPR Foundation
Straub Clinic and Hospital
Honolulu, Hawaii

Photos depicting the personal side of Peter Safar, including his love of music, mountain climbing, and skiing.

[top] Peter Safar (right) mountain climbing on White Mountain,circa 1981.

[center] Drs. Peter Safar and Charles Brindis play a classical piece for four-hands. Anton Bruckner and Gustav Mahler were two of Peter's favorite composers.

[bottom] Former Safar Center fellow, Dr. Sven-Erik Gisvold (left) and Dr. Peter Safar (right) on the slopes at the Seven Springs Ski Resort just east of the city of Pittsburgh, circa 1980. Dr. Gisvold is currently Editor-in-Chief of Acta Anaesthesiologica Scandinavica.

The meetings with Peter Safar left a deep trace in my life. He was self-disciplined, purposeful, incredibly hard working, good-natured, and always in love with the cause to which he devoted all his life. He was highly educated, a real connoisseur of art and music. An amazing party at his place where he played beautifully Mozart and Chopin charmed me. His playing had what some professionals lack — inspiration.

Peter Safar was friendly with Vladimir Negovsky and we know only perfectly well how much Peter did to make the world treat Russia and Russian scientists with respect. His behavior and mode of thinking during the last months of his life from his frequent letters impressed me:

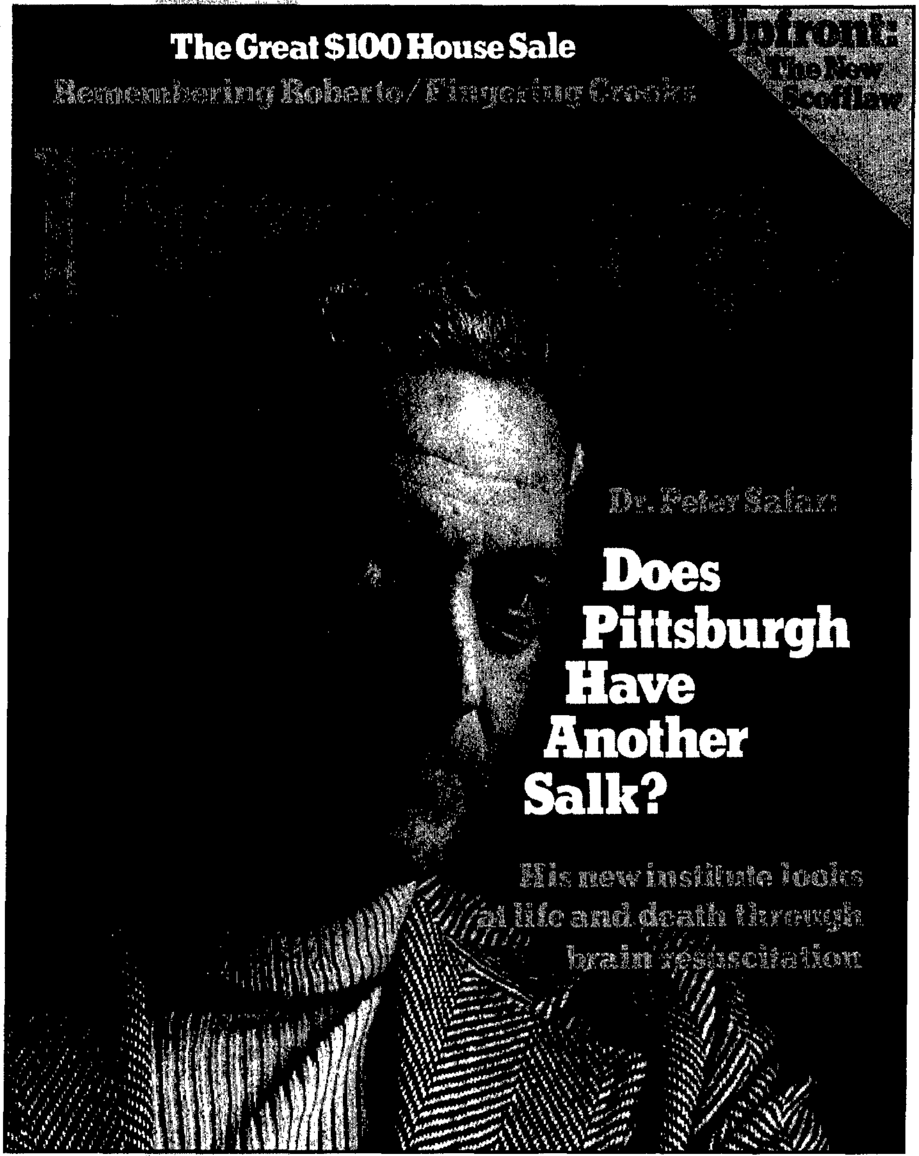
"February 10: Music evening at Dr. Brindis' home. I played two romantic slow movements by Mozart. Both hands now move and feel almost as before the weakness and numbness of October.

It all looked good. He (the reaper), trying to get me because for half a century our work has deprived him of many victims, did not succeed with disease #1 (paralysis), disease #2 (kidney tumor) and disease #3 (gut problems, narcotics, weaning attempts). Philosophically, although April 22 was a death sentence, quality survival time is now my primary consideration. If I survive the operation on May 8, I will fight for every day with a functional brain.

I am in dialogue with the grim reaper. I told him that I am fighting for survival time with quality, and that my associates and former students will continue to resuscitate and to deprive him of his potential victims. My physicians and I are optimistic about shrinkage of my metastases will be accomplished. Ideally, death should come not from the killer of fit young people, but from the angel of death when one's time to depart has come."

I loved him as a person, his humor, and love for life. In my heart he will be forever.

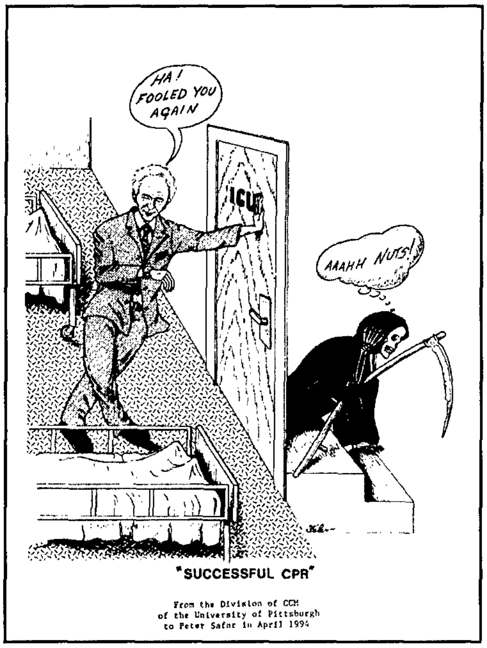
Professor Victor Moroz
Director, Institute for General Reanimatology
Moscow, Russia

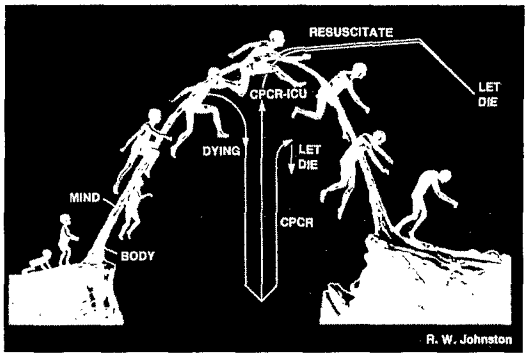


Dr. Safar's international success in the field of resuscitation became legendary in Pittsburgh as shown by the March 1978 cover of Pittsburgh Magazine.

Peter Safar was a man of indomitable resolution who was always completely involved in the task at hand. I remember an all-night imaging experiment where Peter not only was in attendance but personally bought and peeled fruit for the fellows to eat during the long night. His staff and fellows worked hard to meet his expectations because he inspired them by his example and was able to communicate his enthusiasm. It was wonderful that his total commitment and enthusiasm extended to all aspects of his life.

Ann Radovsky, DVM, PhD
WIL Research Laboratories
Ashland, Ohio





[left] Cartoon entitled "Successful CPR" dedicated to Dr. Safar in 1994.

[right] Sculpture entitled "The Nine Ages of Man" by R.W. Johnston, in the University of Pittsburgh School of Medicine. Dr. Peter Safar was constantly striving to facilitate the natural course of this arc of life by preventing sudden cardiac death in people with "hearts and brains too good to die."

I first met Dr. Safar long ago when I was new to the world of CPR and EMS. Although I was just starting out, he believed in me and encouraged me time and time again. He often would review my writing and challenge me to think big, to question conventional wisdom, and to consider things from a global, humanitarian perspective. His guidance to do the right thing, even when it is politically incorrect, is a lesson learned that will always be a part of me.

Like so many others, I have been incredibly honored that Peter took such a sincere interest in my work and life. His philosophy on the need for universal training in life-supporting-first-aid that is simple, straightforward and easily accessible to the public has had a fundamental influence on my career.

More than this, though, Peter influenced my life. Over the years, he met most of my children and made a lasting impact on them, too. It wasn't so long ago that my daughters and I visited with him in his office over the customary espresso and biscotti (with a bottle of red wine handy, of course). He seemed to drop everything, though stacks upon stacks of projects were calling him, so he could give us his full attention. He proceeded to encourage my older daughter in her pursuit of a career in medicine and subsequently emailed back and forth with my younger daughter to help her with a school project.

How did someone as brilliant and prominent as Dr. Safar always find the time for everyone he met, no matter his or her stature? I think it was because he believed so passionately in the goodness of mankind and its potential for even greater goodness.

Thank you, Dr. Safar, for making the world a better place.

Mary Newman
Executive Director
National Center for Early Defibrillation
University of Pittsburgh Schools of Medicine

On our trip to Denver he was suffering from his spinal pain. His pain was so intense that any "normal" individual would need hospitalization to cope with. But he was still determined to attend the meeting.

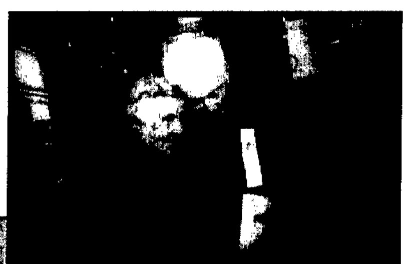
All through the trip he continued to read, prepare his talk, and review my experiments. His talk was amazing, very detailed, accurate, and incredibly advanced and updated. He was without doubt the star of that entire session. He received, of course, considerable admiration from his peers and attendees.

After a well-done job, I thought that he would just relax and take care of his now advanced disease and pain, but not. He continued to meet colleagues, discuss research projects, and plan for future experiments.

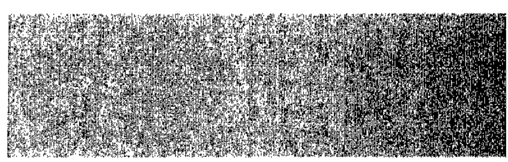
On our way back, we were waiting for the next flight to Pittsburgh. He continued to ask details about our last experiments. I realized that he was in great pain and was trying to find a place where he could lie down so the cervical pain would be relieved. I suddenly found him lying down on the floor, as we did not find a better place. I was going to ask him how I could help, when he just opened his eyes, looked at me with a smile, and asked, "So tell me why do you think that the bleeding is more severe when trauma is added to ischemia in your experiments?"

Ala Nozari, MD, PhD
Former Research Fellow, 2001-2003
Massachusetts General Hospital
Boston, Massachusetts

Mr. Tore Laerdal, son of Asmund Laerdal, Resusci-Anne pioneer, and Dr. Peter Safar at the 20th anniversary celebration of the Safar Center for Resuscitation Research in 2000. Mr. Laerdal is President of Laerdal Medical and developer of Sim Man,which has heightened the Resusci-Anne concept for teaching resuscitation skills to a new level of sophistication.



Dr. Peter and Mrs. Eva Safar at the University of Pittsburgh Honors Convocation, February 2003. Dr. Safar was the keynote speaker and received an honorary Doctorate degree from the University of Pittsburgh, the fourth of his career.



I'm saddened to hear of the death of Dr. Safar. Although I wasn't in his presence much, it was enough to know that, in words I carefully reserve, he was truly one of "God's great creations." There are many people in the world that do good things; however, the number of people at Peter Safar's "level" is much fewer. He truly was a great man and will be sorely missed.

Robert C. Read
Lieutenant Colonel (Retired)
Project Manager, Clinical Applications Division
Telemedicine and Advanced Technology Research Center
Fort Detrick, MD 21702

From left to right, Mr. Robert Read, Mrs. Eva Safar and Colonel Dean Calcagni at the presentation of special recognition to Mrs. Safar by the United States Army Medical Research and Materiel Command for Dr. Safar's important contribution to the treatment of combat casualties. The presentation was held on October 30, 2003, immediately prior to the 24th Annual Peter and Eva Safar Annual Lectureship in Medical Sciences and Humanities. [A photo of this remarkable award appears on the first page of the tribute section.]

There is a lot to be thankful for and a lot of things to say about Peter Safar. He was a pioneer in anesthesia and intensive care medicine and dedicated his life to science. He educated many to become established researchers and was very eager to keep his international contacts, especially the bridge between Europe and the USA. I will also always remember Peter for the discussions about life and science at the local Chinese restaurant while drinking plum wine.

Sten Rubertsson, MD, PhD, EDIC
Associate Professor, Clinical Reader
Department of Surgical Sciences/Anesthesiology & Intensive Care
Uppsala University Hospital

My first meeting with Peter Safar took place in the lobby of the Sheraton Hotel in Boston on a cold February day in 1966. I was in the last months of my anesthesiology residency and as I was interested in the new field of "Acute Medicine," my mentor, Leroy Vandam, suggested that I contact the new up-and-coming star in this area - Peter Safar. As suggested, we met in the lobby of the hotel, where Peter was sitting with the now familiar files on his lap and countless rubber bands on his wrist. Attached to one of his files was my photo, and I was greeted with "Dr. Smith, pleased to meet you. So you want to be an Intensivist?"

Jan Smith, MB, ChB, MRCP
Professor & Vice Chairman
Department of Anesthesiology
Professor of Internal Medicine
University of Pittsburgh

In the late winter of 1952, the anesthesia department received its first supply of the new neuromuscular blocker succinyl choline. We had read about its rapid onset and offset and its paralyzing dose of about 100 mg for an adult. Before using it on patients, Peter Safar and I agreed to test it on each other. I was the first subject. In an anesthesia induction room, I lay on a stretcher with an anesthesia machine beside me. Peter injected a small dose, 20 mg, IV, which we assumed would only partially paralyze me. Within 20 seconds I discovered that I could not breathe or talk but could still use my arm. I reached for the anesthesia mask and tubing hanging beside me as if to alert Peter that I needed oxygen. Then my arm collapsed. He didn't get the message. But within a minute he noted my total paralysis and then put the mask on and gave me oxygen. In less than two minutes I was able to breathe, to sit up, then to stand up, then to jump up and down to prove that my strength had come back. However, the drug had given me intense lumbar back and thigh pain with the muscular fasciculations that occur as it depolarizes the neuromuscular junction, and that pain lasted many days. We cancelled doing the same thing to Peter.

John Severinghaus, MD
Ross, CA

From left to right: Drs. Lyn Yaffe, Patrick Kochanek, Florence Rollwagen and Peter Safar. Dr. Safar and Dr. Yaffe, former Director of Research and Development at the Naval Medical Research and Development Command and Combat Casualty Care Research area manager, at one of many meetings related to combat casualty care research. Dr. Safar's work in combat casualty care involved important interactions with both the U.S. Army and the U.S. Navy.

From left to right, Denise Kochanek, Dr. Peter Safar, Eva Safar and Dr. Patrick Kochanek celebrating the turning over of leadership of the Safar Center for Resuscitation Research to the younger generation in 1994. This photo was taken from the top of Mt. Washington, which boasts a great view of the city of Pittsburgh and was used by Dr. Safar during his career to recruit over 100 faculty members to the University of Pittsburgh.

When Mistress Medicine called nothing else seemed to matter to Peter or to any of us bound to him. A patient in crisis could not be denied, nor a trainee like me, who could ignore the Do Not Disturb sign on his office door, knock twice, and walk in to discuss a vital patient issue. He didn't mind and I knew he didn't mind, being disturbed. We were, after all, on the same mission.

His ideas appealed to my own desire to rescue patients at the edge of the abyss. His call for action was so clear that there was no sensible alternative: we can and we must. Peter's ideal physician would meet the patient in the field and escort him personally through the crisis. Effective restoration of breath in the service of life was his most obvious focus, and the quality of life as mediated through effective resuscitation of the brain was his larger concern. Peter also taught me what should happen when Death is inevitable. He railed vehemently against the stupidity or naiveté of those who refused to acknowledge when Death had won and demanded that palliative care receive as careful an effort as had rescue therapy.

What Peter the Idealist accomplished and taught was transformative. That his views eventually held sway, that the entire ICU team, led by the intensivist, should work together and treat the whole patient, is a tribute not just to his tenacity and powers of persuasion, but to the views themselves.

Thirty-five years after my life-changing encounter with Peter, his compelling personality, ability to inspire, and moral compass still resonate. What halcyon days to be so led!

James V. Snyder, MD
Professor, Department of Critical Care Medicine
University of Pittsburgh

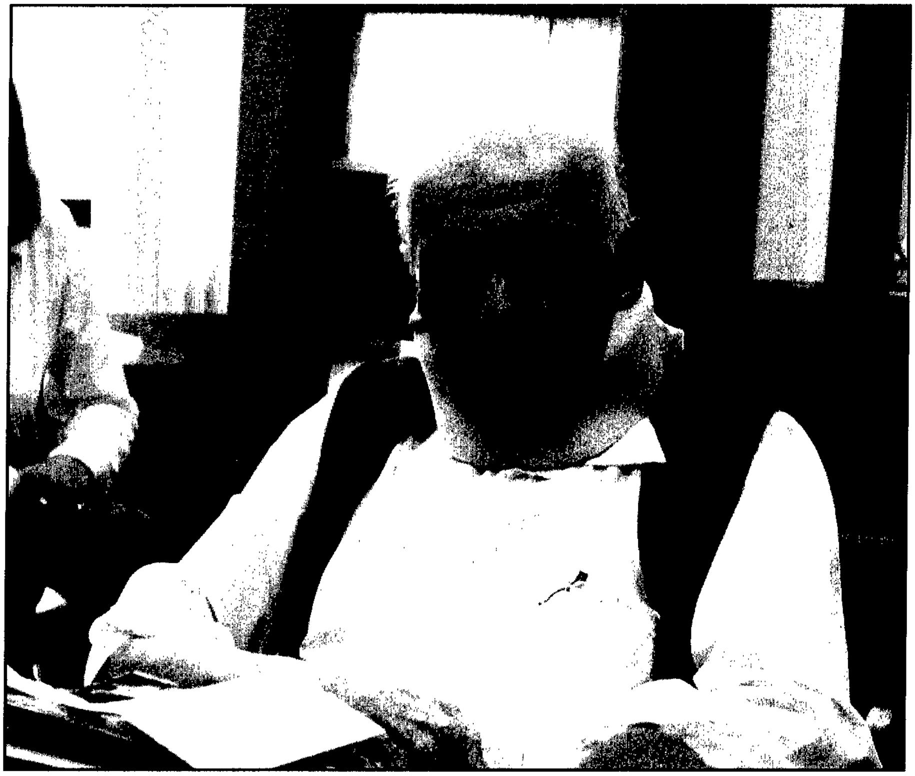
In 1993 Peter prompted me to carry his life supporting first aid (LSFA) message to the masses and in turn became my mentor, confidante, and friend while carrying on this mission. His humanitarian efforts and research, along with his genuine charisma, will forever be remembered and cherished. As he was responsible for cradling so many souls back to life, he will always be remembered for his endeavors towards giving all human kind a "second chance."

Carol Spizzirri, RN
Founder, Save A Life Foundation
Chicago, IL

Lessons from Dr. Peter Safar:

- First and foremost, our role in life is to do something worthy of being written about or to write something worthy of others to read.
- All of us need to be devoted to the profession and strive to seek excellence daily in our efforts.
- Altruism is the essence for mankind. In one of his last letters to me he said, "Keep up your good missionary work." This truly was his mission in life for himself. He strived to instill this in all that he touched.
- Work hard, play hard, and live life to its fullest.
- Get to work early and stay late.
- Work with every individual and organization that is in position to make a difference.
- Find a purpose and devote your life's work to it.

Walt Stoy, PhD, EMT-P, CCEMT-PE
Professor and Director, Emergency Medicine Program
School of Health and Rehabilitation Sciences
University of Pittsburgh



Dr. Peter Safar at his 79th birthday celebration at the Safar Center for Resuscitation Research, April 12, 2003. Despite extensive metastatic cancer, Dr. Safar made important contributions to the mission of the Safar Center until two weeks before his death on August 3, 2003.

Peter Safar touched countless lives through his many contributions to resuscitation, critical care, and anesthesiology. In the history of medicine, very few physicians and scientists have had such an impact. Like the ripple on the pond that spreads in waves in all directions, Peter's legacy will continue to spread through those of us who had the great fortune of knowing him, working with him, or training with him (not "under" him, for he treated everyone as equal colleagues).

As we celebrate Peter's unique academic achievements, let us not forget his clinical side. He was an outstanding anesthesiologist. In the operating room, he devoted the same energy to patient care that, outside the OR, he devoted to research; always putting the patient first. His exploits were legendary. He was renowned for turning off the monitors and telling the residents, "(Pointing to the carotid pulsation.) Here is your EKG and blood pressure monitor. (Pointing to the tongue.) Here is your pulse oximeter. (Pointing to the pupils.) Here is how you monitor the depth of anesthesia." He was able to push trainees to their limits, safe in the knowledge that he could handle anything that might arise.

Peter's artistic, specifically musical, side was evident as he would describe an operation as "chamber music" in which all participants know their parts and no single leader is needed "to make beautiful music together." This was perhaps to the chagrin of surgical colleagues who think of operations more as symphonies, with the surgeon as conductor. Peter easily gained the respect and admiration of those of us on the other side of the ether curtain.

Peter Safar, our leader, teacher, mentor, and friend, will sorely be missed, but he has left his indelible mark on each of us and all of humanity.

Samuel A. Tisherman, MD
Associate Professor, Surgery and Critical Care Medicine
University of Pittsburgh

My most memorable time with Peter was when he was interviewing me for the Chair. He asked me, "What do you want to do with your life?" I told him I wanted to build a department that was world-renowned. He replied, "Yes of course, but what are you going to do to change the world?" That in one question is the way that Peter looked at the world. It was simply part of what one does in their life. One is expected to change the world no matter who you are or what you do. He was one of the most impressive men I have ever had or hope to have the chance to meet. Thanks for letting me get to know him.

John P. Williams, MD
Peter and Eva Safar Professor
Anesthesiology Chair
University of Pittsburgh
Pittsburgh, PA 15261

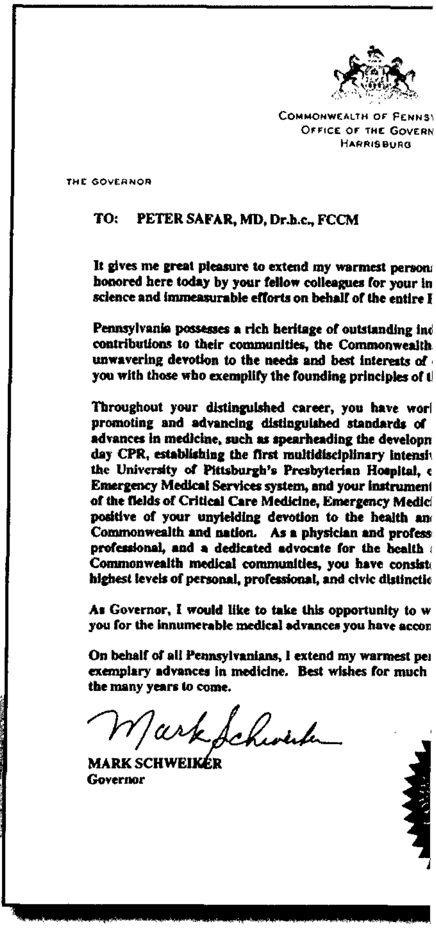
Dr. Safar was a key influence in our society, beginning with our predecessor organization, the University Association for Emergency Medicine, through today's Society for Academic Emergency Medicine. He shared his work and encouraged his trainees, many of whom are research and thought leaders in our field and our society, to join, to participate, and to improve the knowledge that has altered the care of the sickest patients. Much of our current success is due to Dr. Safar and his efforts; that legacy will endure.

Donald M. Yealy, MD
President, Society for Academic Emergency Medicine

Peter Safar in his home office, spring 1995.

Dr. Peter Safar had an enormous impact on so many individuals through his academic career, scientific leadership, personal warmth, and generosity. With certainty, he will never be forgotten, not only through the Center, lecture and symposia that bear the Safar name, but through the ongoing work of his students and associates who have learned the importance of deep caring and commitment to each person's well-being. I had the lasting pleasure of being a friend since the mid-1990's beginning at a "Lazarus meeting" to explore novel research topics for resuscitation of combat casualties. That friendship and dedication to advanced resuscitation techniques, particularly therapeutic hypothermia and suspended animation, has been a lasting inspiration to me. The vision of Dr. Safar will continue to inspire, and the dedication to his goals will remain strong. He leaves a lasting legacy, particularly through those countless individuals who never knew his name, but live and benefit because of his research and achievements in resuscitation and critical care medicine.

Lyn Yaffe, MD
Medical Director, Yaffe LLC
Former Director, Research & Development
Naval Medical Research & Development Command



COMMONWEALTH OF PENNS
OFFICE OF THE GOVERN
HARRISBURG

THE GOVERNOR

TO: PETER SAFAR, MD, Dr.h.c., FCCM

**It gives me great pleasure to extend my warmest person
honored here today by your fellow colleagues for your in
science and immeasurable efforts on behalf of the entire**

**Pennsylvania possesses a rich heritage of outstanding in
contributions to their communities, the Commonwealth
unwavering devotion to the needs and best interests of
you with those who exemplify the founding principles of**

**Throughout your distinguished career, you have wor
promoting and advancing distinguished standards of
advances in medicine, such as spearheading the developm
day CPR, establishing the first multidisciplinary intensi
the University of Pittsburgh's Presbyterian Hospital,
Emergency Medical Services system, and your instrumen
of the fields of Critical Care Medicine, Emergency Medic
positive of your unyielding devotion to the health an
Commonwealth and nation. As a physician and profess
professional, and a dedicated advocate for the health
Commonwealth medical communities, you have consist
highest levels of personal, professional, and civic distincti**

**As Governor, I would like to take this opportunity to w
you for the innumerable medical advances you have accom**

**On behalf of all Pennsylvanians, I extend my warmest pe
exemplary advances in medicine. Best wishes for much
the many years to come.**

Mark Schweiker

**MARK SCHWEIKER
Governor**

University of Pittsburgh

Safar Center for Resuscitation Research

Office of the Director

3434 Fifth Avenue
Pittsburgh, Pennsylvania 15260 USA
412-624-6735
Fax: 412-624-0943

July 1, 1994

Dr. Peter Safar
International Resuscitation Research Center
University of Pittsburgh

Dear Dr. Safar,

I write this letter to you as my first official act as the newly appointed Director of the International Resuscitation Research Center. Unless you object, I would very much like to rename the Center in your honor. The most logical choice for the new name of the IRRC, is the **"Safar Center for Resuscitation Research."** Although this stationary is not finalized, I present you with this first letter as a memento of this event. It is my hope that the title "Safar Center" catches on as the new name for the institute. Clearly it is a name synonymous with resuscitation medicine.

I look forward to this exciting new challenge and thank you for this opportunity.

Best,

Patrick M. Kochanek, M.D.
Director, Safar Center

Commanding General
US Army Medical Research and Materiel Command
and Fort Detrick
Fort Detrick, Maryland 21702-5012

October 29, 2003

Dear Mrs. Safar:

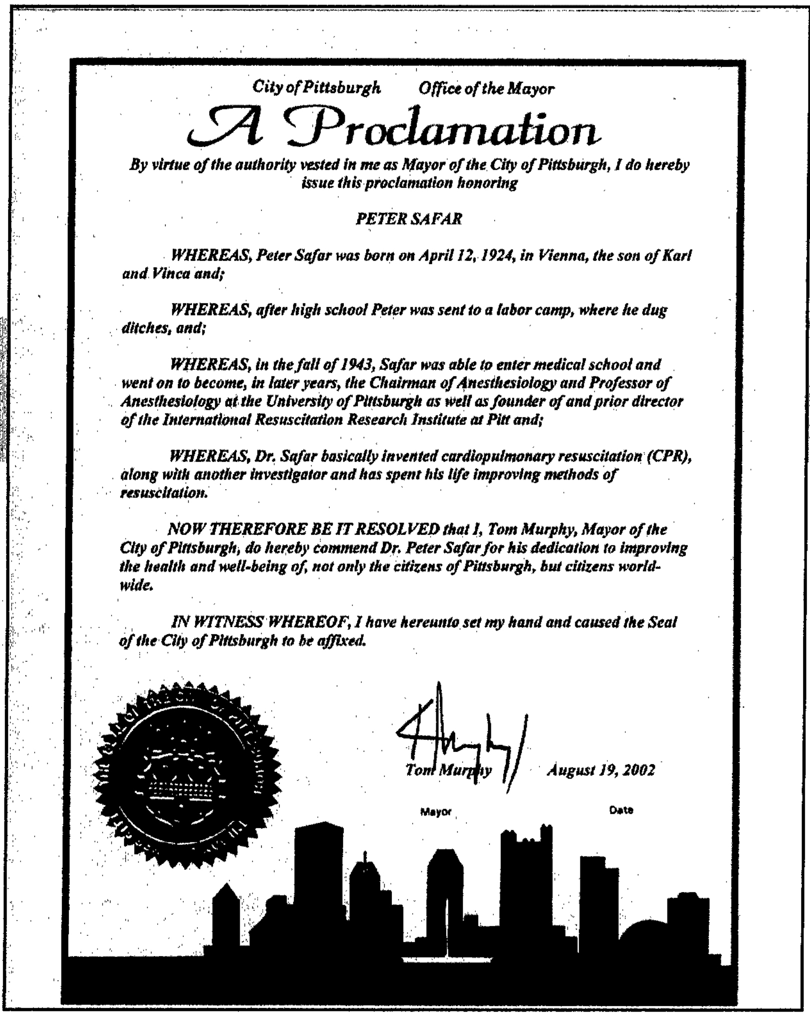
On behalf of the entire US Army Medical Research and Materiel Command and Fort Detrick, I want to express my deepest sympathy to you and your family upon the death of your husband, Dr. Peter Safar.

Although I did not personally know your husband, I want to recognize his remarkable contributions to resuscitation medicine which have had an enormous impact on combat casualty victims in the United States military. His accomplishments included fundamental contributions to the development of cardio-pulmonary resuscitation, the establishment of the first intensive care units, and the creation of the Safar Resuscitation Center.

The Army owes Peter Safar a great debt of gratitude for all of his ground breaking work to radically improve the care and survival for severely injured people. You can be very proud of your husband's accomplishments. Please accept the thanks of a grateful Nation.

Sincerely,

Lester Martinez-Lopez, MD, MPH
Major General, Medical Corps
Commanding



City of Pittsburgh Office of the Mayor

A Proclamation

By virtue of the authority vested in me as Mayor of the City of Pittsburgh, I do hereby issue this proclamation honoring

PETER SAFAR

WHEREAS, Peter Safar was born on April 12, 1924, in Vienna, the son of Karl and Vinca and;

WHEREAS, after high school Peter was sent to a labor camp, where he dug ditches, and;

WHEREAS, in the fall of 1943, Safar was able to enter medical school and went on to become, in later years, the Chairman of Anesthesiology and Professor of Anesthesiology at the University of Pittsburgh as well as founder of and prior director of the International Resuscitation Research Institute at Pitt and;

WHEREAS, Dr. Safar basically invented cardiopulmonary resuscitation (CPR), along with another investigator and has spent his life improving methods of resuscitation.

NOW THEREFORE BE IT RESOLVED that I, Tom Murphy, Mayor of the City of Pittsburgh, do hereby commend Dr. Peter Safar for his dedication to improving the health and well-being of, not only the citizens of Pittsburgh, but citizens world-wide.

IN WITNESS WHEREOF, I have hereunto set my hand and caused the Seal of the City of Pittsburgh to be affixed.

Tom Murphy *August 19, 2002*

Mayor Date

Peter Safar was a "giant" in the field of resuscitation. He was a founding father of this field and because of his insight, enthusiasm, and hard work, scores and scores of young and old scientists and clinicians have entered this area over the years. Peter was an engaging man with a quick-witted sense of humor and always knew what to say and how to say it in order to make someone feel special. I remember meeting him at one of the many resuscitation meetings we frequented and as we were discussing cardiac arrest/CPR at a poster session, he was continuously taking copious notes in a little notebook. In fact, he was writing so fast and furiously that it was a true distraction to me. I said, "Peter, why are you taking all these notes? Come on, it's me, Dick. You don't have to take notes. Let's just talk and argue." His response was classic Peter Safar: "I'm writing everything down because I don't want to forget the many important things you have to say here."

Richard J. Traystman, PhD
Associate Vice President for Research Planning and Development
Professor, Anesthesiology and Peri-Operative Medicine
Oregon Health and Science University
Portland, Oregon

Introduction to the Proceedings of the Second Annual Safar Symposium

Patrick M. Kochanek, MD, FCCM; Ake Grenvik, MD, PhD, FCCM; John Schaefer, MD

In the winter of 2002, the idea that an annual Safar Symposium be held at the University of Pittsburgh School of Medicine was put forth by John Williams, MD, chairman of the department of anesthesiology, University of Pittsburgh School of Medicine. Fortunately, Dr. Safar was able to take part in the first Safar Symposium in November of 2002. After an initial success in 2002, the second Safar Symposium was held—in conjunction with a memorial service to him—on October 30, 2003, in the Bioscience Tower at the University of Pittsburgh School of Medicine. The conference attracted about 150 clinicians and scientists from around the world and was sponsored by the U.S. Army Medical Research and Materiel Command. Selected portions of the proceedings of the Second Annual Safar Symposium are published as short articles on the pages that follow.

The proceedings highlighted two important aspects of Peter Safar's illustrious career, namely, resuscitation and education, and two important links that Peter Safar very much desired to see carried on in perpetuity—the link between the Safar and Laerdal legacies at the University of Pittsburgh and the strong relationship between the Safar Center for Resuscitation Research at the University of Pittsburgh, directed by Dr. Patrick Kochanek, department of critical care medicine, and the Winter Institute for Simulation, Education, and Research at the University of Pittsburgh, directed by Dr. John Schaefer, department of anesthesiology. The latter of these honors Dr. Peter Winter, former chairman of the department of anesthesiology, who followed Peter Safar in that role at the University of Pittsburgh. To that end, the Safar Symposium this year was composed of a morning session entitled "Breakthroughs in Resuscitation" and an afternoon session entitled "Advances in Human Simulation Education."

In 2003, the morning session focused on the use of hypothermia in resuscitation and neurointensive care. It featured *six lectures by experts in the use of hypothermia in experimental and clinical brain injury.* The topic of protective mechanisms of hibernation was addressed by Dr. John Hallenbeck, chief of the stroke branch at the National Institute of Neurologic Disorders and Stroke. The deleterious effects of rapid rewarming were discussed by Dr. John Povlishock, chairman of the department of anatomy at the Medical College of Virginia. The use of controlled normothermia to prevent secondary damage in neurointensive care was covered by Dr. Donald Marion, chairman of the department of neurologic surgery at the Boston University School of Medicine. A novel concept of using hypothermia-induced "suspended animation with delayed resuscitation" for otherwise unresuscitable combat casualties was the topic of Dr. Samuel Tisherman, associate director of the Safar Center and associate professor of surgery and critical care medicine at the University of Pittsburgh School of Medicine, and "smart catheter" strategies for rapid central cannulation in the field were addressed by former United States Naval Medical Research Institute director Dr. Lyn Yaffe of Alion Sciences.

The use of hypothermia in cerebral protection and resuscitation was a topic of great interest to Peter Safar because it was the therapy that had the greatest effect in all of the experimental models of cardiac arrest and shock that he studied during his career. Indeed, Dr. Safar recommended therapeutic hypothermia as part of an expanded ABC (airway, breathing, and cardiac compression) in a paradigm for Emergency Medical Services systems in the treatment of cardiopulmonary arrest as early as 1964 (1). The recent level I recommendation by the International Liaison Committee on Resuscitation, including the American Heart Association, supporting the use of mild hypothermia after cardiopulmonary arrest in adults has produced a tremendous surge in the interest and use of this promising therapy across the collective fields of acute medicine (2). The speakers addressed topics of great relevance to both our understanding of this therapy and its potential for novel future applications throughout acute medicine. The session was moderated by Dr. Clifton Callaway, associate professor in the University of Pittsburgh Center for Emergency Medicine, and Colonel Dean Calcagni, Deputy Director, Telemedicine and Advanced Technology Research Center, United States Army Medical Research and Materiel Command.

The afternoon session, "Advances in Human Simulation and Education," included six lectures. Dr. Doris Ostergaard, director of the Danish Institute of Medical Simulation, spoke on the renowned national simulation medical training program in Denmark. Dr. Michael DeVita, associate professor of internal medicine and critical care medicine at the University of Pittsburgh, spoke on the use of simulation in code team training to prevent medical errors. Dr. William Mc Ivor, assistant professor of anesthesiology at

Director, Safar Center for Resuscitation Research, Professor and Vice Chairman, Department of Critical Care Medicine, University of Pittsburgh School of Medicine, Pittsburgh, PA (PMK); Director, Winter Institute for Simulation, Education, and Research, Associate Professor, Department of Anesthesiology, University of Pittsburgh School of Medicine, Pittsburgh, PA (JS); Distinguished Service Professor, Department of Critical Care Medicine, University of Pittsburgh School of Medicine, Pittsburgh, PA (AG).

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the University of Pittsburgh, discussed the use of simulation training for medical students during their anesthesiology clerkship. Dr. Paul Rogers, professor of critical care medicine at the University of Pittsburgh and respected expert in resident, fellow, and medical student education at the University of Pittsburgh, focused on the use of simulation in critical thinking by medical students. Finally, Mr. Tore Laerdal, president of Laerdal Medical, and Dr. Melinda Fiedor, clinical instructor and National Institute of Child Health and Human Development research fellow at the Safar Center and Winter Institute, addressed the topic of new areas for the use of simulation in medical education—including the hot topic of the potential applications of medical simulation in pediatric resuscitation and critical care medicine. Drs. Ake Grenvik, distinguished service professor of critical care medicine, and Peter M. Winter, professor and emeritus chairman of the department of anesthesiology, University of Pittsburgh School of Medicine, moderated this session on human simulation.

We would like to personally thank the United Sates Army Medical Research and Materiel Command, including the efforts of Colonel Dean Calcagni and Mr. Robert Read, for generous support of the symposium. We also thank Drs. John Williams, chairman of the department of anesthesiology, and Mitchell Fink, chairman of the department of critical care medicine, for additional support of this symposium. We thank Linda Amick, Fran Mistrick, Marci Provins, Valerie Sabo, and Christopher Edwards for their administrative and technical efforts on the symposium. Finally, we are very grateful to the authors of the articles in this supplement, both for coming to Pittsburgh to honor Dr. Safar and for their prompt delivery of their manuscripts, despite the hectic schedules we all face in 21st century academic medicine.

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Controlled normothermia in neurologic intensive care

Donald W. Marion, MD

Preclinical and clinical studies of therapeutic hypothermia completed during the last 15 yrs have dramatically expanded our understanding of this treatment for a variety of neurologic diseases, especially traumatic brain injury (TBI), stroke, and cardiac arrest. With few exceptions, the preclinical studies have shown that cooling of the brain to 32–33°C after trauma or ischemia leads to reduced levels of excitotoxic amino acids, reduced inflammation, a reduction in the volume of tissue damaged, and improved functional outcomes. Recently, two clinical trials studied the use of this treatment for patients with cardiac arrest and found improved outcomes for those cooled to 32–33°C for 12 or 24 hrs after the arrest (1, 2).

However, the efficacy of hypothermia for patients with severe TBI is not as clear. Although small clinical trials completed during the 1990s found benefit for subgroups of TBI patients treated with hypothermia (3, 4), Clifton et al. (5) did not find any benefit in a large, multiple-center trial of 392 patients completed in 2001. The results of this trial were surprising given the strong preclinical evidence in support of the efficacy of hypothermia for TBI and given the results of the smaller, single-center studies. Clifton et al. (5) also found that hypothermia was effective in reducing intracranial pressure. However, elevated intracranial pressure is closely associated with poor outcomes, so the results of the study by Clifton et al. (5) raise confusion about the link between intracranial pressure and outcomes. Based on the results of this trial, Safar et al. (6) have raised serious questions about the ability to conduct multiple-center clinical trials sufficiently controlled to allow for meaningful results. A subsequent analysis (7) of the consistency with which patients were medically managed in the study by Clifton et al. (5) seems to confirm some of the suspicions of Safar et al (6).

It also is possible, however, that therapeutic hypothermia is not as important in preventing secondary injury as is the prevention of fever. In the study by Clifton et al. (5), the temperature in the normothermia patients was tightly controlled to 37–38°C, and fever was aggressively treated. Such close attention to the prevention of fever in the control group may have reduced the expected morbidity and mortality in that group, resulting in outcomes that were similar to the hypothermia group. Several retrospective studies of patients with stroke, spontaneous intracranial hemorrhage, and subarachnoid hemorrhage have found an association between fever and poor outcomes. In this article, I will review studies that describe potential deleterious effects of fever and the incidence of fever in a typical neurologic intensive care unit (ICU), and I will conclude with results of a clinical trial that used an invasive temperature-modulation device to prevent fever in the ICU.

Laboratory Evidence of the Effects of Fever

In animal models of ischemia and of percussive or contusive brain injury, brain temperatures of >39°C are associated with an increase in the extracellular levels of excitatory amino acids and free radicals and with more extensive breakdown of the blood–brain barrier, increased enzymatic inhibition of protein kinases, and worsened cytoskeletal proteolysis (8). In a rodent ischemia model, hyperthermia (39°C) superimposed on transient ischemia led to a ten-fold increase in ischemic neurons and a significant increase in calpain activation and spectrin degradation (9). Others have found that the deleterious effects of hyperthermia are not confined to the time immediately after the insult. In their rodent ischemia model, Baena et al. (10) showed that even at 24 hrs after the insult, brain temperatures of >39°C led to a significant increase in the number of ischemic neurons in selectively vulnerable brain regions.

Clinical Evidence of Adverse Effects of Fever

Several retrospective studies have found a significant association between fever and outcomes after intracerebral hemorrhage, subarachnoid hemorrhage, and stroke. In their study of 196 patients with spontaneous intracerebral hemorrhage, Schwarz et al. (11) found significantly worse outcomes for those who had rectal temperatures of >37.5°C than those who did not. Oliveira-Filho et al. (12) reviewed the outcomes of 92 patients with subarachnoid hemorrhage, and found that 38 of these patients had rectal temperatures of >38.3°C for ≥2 days during the first week after hemorrhage. The odds ratio for poor outcomes (death, vegetative survival, or severe disability) in the subgroup with fever was 1.4 (95% confidence interval, 1.1–1.88) when compared with the patients who had no fever. Several studies have shown a similar effect of fever on poor outcomes for patients with stroke (13–15). In a meta-analysis of those studies by Hajat et al. (16), fever after stroke was found to be associated with a significant increase in neurologic morbidity ($p < .0001$) and with a highly significant increase in death ($p < .000001$).

Fever in the Neurologic ICU

Those who treat critically ill patients with neurologic disease are well aware that fever is a common problem during

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Key Words: controlled normothermia; therapeutic hypothermia; traumatic brain injury

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the first several weeks after the insult. The most common cause is nosocomial infection, and endotracheal intubation is a well-known independent predictor of pneumonia. These patients usually require intravenous and intra-arterial catheterization for the administration of fluids and for continuous monitoring of blood pressure and central venous pressure, but such catheterization also increases the risk for infection and sepsis. Other causes of fever are atelectasis, particularly in postsurgical patients who are not intubated. Fever is a common side effect of phenytoin, an anticonvulsant frequently used for trauma patients and patients with intracranial hemorrhage. The presence of blood in the subarachnoid space also has been implicated as a central cause for fever.

In 1999, we reviewed the incidence of fever in the neurologic ICUs of our hospital (17). During a 12-month period, 428 patients were admitted with stroke (34%), severe TBI (32%), subarachnoid hemorrhage (13%), and a smaller proportion of other acute neurologic diseases. Rectal temperatures were routinely obtained and recorded every 2–4 hrs. For the purposes of this study, a febrile episode was defined as a rectal temperature of >38.5°C. In all cases, the nursing staff was directed to aggressively treat fever with acetaminophen and cooling blankets. Despite this directive, febrile episodes occurred in 46.7% of the patients. There was no apparent correlation with their admission diagnosis, but there was a significant correlation with length of stay in the ICU: febrile episodes were observed in only 15.5% of those who spent <24 hrs in the ICU but occurred in 92.6% of those who were in the ICU for ≥2 wks. Other studies have found an even higher incidence of fever for patients in the ICU, confirming a strong association with duration of ICU stay and with endotracheal intubation (18).

Correlation of Brain Temperature with Rectal and Bladder Temperature

Another concern, and one that is certainly magnified by the animal studies showing a strong association between secondary brain injury and elevated brain temperatures, is the observation that brain temperatures are usually higher than rectal or bladder temperatures after TBI. We compared brain, rectal, and bladder temperatures for 5 days in eight patients with severe TBI (19). Deep brain temperatures were measured using a microthermister attached to a ventriculostomy catheter. Simultaneous brain, bladder, and rectal temperatures were obtained each minute during that time, for a total of 30,000 measurements. At virtually all time points, the brain temperatures were higher than the rectal or bladder temperatures. Brain temperatures averaged 1°C higher than rectal temperatures, and in nearly 10% of measurements, brain temperatures were 2°C higher. The differences between brain and bladder temperatures were slightly less, on average, 0.8°C. However, differences were greatest when the rectal or bladder temperatures were elevated. Thus, patients with rectal temperatures of 38–39°C were very likely to have brain temperatures of 40–41°C. Rumana et al. (20) completed a similar study of brain and systemic temperatures in patients with severe TBI and found that brain temperatures were frequently 1.1°C higher then rectal temperatures. Jugular venous temperatures were measured and were found to correlate with core body temperatures, but not with brain temperatures. The greatest differences between brain and core body temperatures were observed when the cerebral perfusion pressure decreased to <50 mm Hg and the smallest differences when patients were treated with high-dose barbiturates for control of elevated intracranial pressure.

Can the Incidence of Fever in the ICU be Reduced?

During the last decade, several groups have developed invasive devices designed to more rapidly reduce body temperature or to better maintain normal temperature. Laboratory investigations have shown that direct cooling of the venous blood with heat-exchange devices inserted into the vena cava can more rapidly cool the patient, or better maintain normal temperature, than surface cooling techniques. In 2000, a multiple-center clinical trial was initiated by the Alsius Corporation to determine if a heat-exchange catheter it developed could significantly limit the incidence of fever in patients with several acute neurologic diseases. Twelve hospitals participated in the study and enrolled 296 patients. Adult patients with spontaneous intracerebral hemorrhage, subarachnoid hemorrhage, severe TBI, and severe cerebral infarction were studied. Patients were randomly assigned to a group of patients who had their body temperature regulated via a heat-exchange catheter placed into the superior vena cava or a group of patients who had conventional fever management using antipyretic medication and cooling blankets. The former group had the heat-exchange catheter placed into the superior vena cava by percutaneous insertion through the subclavian or internal jugular vein, and cooled saline was infused through two heat-exchange balloons attached near the distal end of the catheter. The temperature of the saline solution infused through the balloons was adjusted automatically according to feed back to the external pump/refrigerant device from a microthermister attached to a Foley bladder catheter. The device was set to maintain a body temperature of 37°C. In the control group, temperatures of >38°C were aggressively treated with a acetaminophen, ibuprofen, and cooling blankets as needed. The primary end point of the study was the time the bladder temperature was of >38°C, expressed as the "fever · time product," during a 72-hr interval beginning soon after admission to the ICU. At the completion of patient enrollment, the majority of patients had either subarachnoid hemorrhage or severe TBI as their primary diagnosis, and patients in both the control and experimental groups had a similar distribution of diseases. Likewise, the age, sex, race, weight, body mass index, Glasgow Coma Scale score, and National Institutes of Health Stroke Scale score were not significantly different between the two groups. Final analyses of the temperature data revealed that there was a 64% reduction in the fever burden for patients with the heat-exchange catheter compared with the control patients.($p <$ .0001). Differences between the two groups were comparable among study sites and among presenting diseases. There also was a 61% reduction in the use of cooling blankets, 66% reduction in the use of other physical means of cooling, and 28% reduction in the use of antipyretic agents in the heat-exchange catheter group. There was no significant difference in the use of antibiotics or sedatives between the two groups. There was no increase in the incidence of infection, sepsis, deep venous thrombosis, or other medical complications attributable to the heat-exchange catheter. *Post hoc* analysis also revealed that the fever burden was significantly higher in patients who died

Intravascular temperature modulation has been shown to be more effective for preventing fever than conventional methods, such as antipyretic medications or surface-cooling techniques.

(13.1°C hours) than in those who survived (7.7°C hours).

Summary

Preclinical studies of cerebral ischemia and trauma find increased brain tissue injury and worsened functional outcomes if the brain temperature exceeds 39°C. Several retrospective studies of patients with new-onset stroke, intracerebral hemorrhage, or subarachnoid hemorrhage support these observations. However, fever is very common among these patients early after the onset of their disease, particularly if they are in the ICU for a week or more, and brain temperatures are likely to be as much as 2°C higher than rectal temperatures. Finally, intravascular temperature modulation has been shown to be more effective for preventing fever than conventional methods, such as antipyretic medications or surface-cooling techniques. Further study is needed to establish if such better control of temperature will lead to improved outcomes.

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Suspended animation for resuscitation from exsanguinating hemorrhage

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Cardiopulmonary resuscitation with artificial respirations and external chest compressions have enabled initiation of lifesaving interventions by lay persons and medical personnel, anywhere, anytime (1, 2). During normovolemic cardiac arrest, external chest compressions have a physiologic basis for efficacy. Open-chest cardiopulmonary resuscitation is physiologically superior (3, 4), although clinical studies have been inconclusive (5, 6). During exsanguination cardiac arrest, however, external chest compressions are not physiologically effective. Clinically, trauma victims who suffer cardiac arrest from exsanguination have almost no chance for intact survival, even after emergency department thoracotomy and open-chest cardiopulmonary resuscitation (7). Rapid attempts at fluid resuscitation and hemostasis lose the race against the tolerance limits for complete ischemia of 5 mins for the brain (8) and about 20 mins for the heart (8, 9).

The majority of soldiers killed in action in Vietnam without brain trauma had penetrating truncal injuries (10). They exsanguinated internally within a few minutes. Such casualties are still considered unresuscitable, although many have technically repairable injuries on autopsy. In 1984, Bellamy, a U.S. Army surgeon, and Safar met and pondered recent military casualty data and agreed that a novel approach was necessary (i.e., suspended animation). Suspended animation is defined as treatment to preserve the viability of the entire organism during ischemia, such as no flow (cardiac arrest) or low flow (shock). The goal is to induce suspended animation with hypothermia, drugs, and fluids. If instantaneous preservation of the viability of brain and organism could be achieved, one could buy time for transport and major hemostasis during clinical death, to be followed by restoration of blood volume and resuscitation, using cardiopulmonary bypass (CPB).

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Suspended Animation Animal Outcome Studies

Since the late 1980s, researchers at the Safar Center for Resuscitation Research of the University of Pittsburgh have been engaged in systematic outcome studies in dogs for the development of suspended animation (11). In the initial series of experiments, Tisherman et al. (12–16) and Capone et al. (17) explored hypothermic preservation at tympanic membrane temperatures (Tty) of 15°C (deep hypothermia) or 5–7°C (profound hypothermia) after 30 mins of hemorrhagic shock at a mean arterial pressure 40 mm Hg. Suspended animation was induced by closed-chest CPB with hemodilution by crystalloids. After circulatory arrest of 60–120 mins, CPB was used for reperfusion and rewarming. Tty of 34°C was maintained for 12 hrs, controlled ventilation to 24 hrs, and intensive care to 72 hrs. End points included functional outcome in terms of overall performance categories (OPC 1 = normal, 2 = moderate disability, 3 = severe disability, 4 = coma, 5 = death) and neurologic deficit scores (0–10% = normal, 100% = brain death). Standardized necropsy included perfusion fixation of the brain and histopathologic damage scoring of 19 brain regions.

Profound cerebral hypothermia (Tty 5–7°C) induced at the beginning of exsanguination cardiac arrest improved neurologic outcome compared with that with deep hypothermia (15°C) (12, 13). The University of Wisconsin organ-preservation solution in the microcirculation during circulatory arrest did not add cerebral benefit over that achieved with standard plasma substitutes (14). These initial studies had been performed with standard CPB systems and systemic anticoagulation, which would be contraindicated after trauma. In a separate study, use of a heparin-bonded CPB circuit without systemic anticoagulation did not offset the beneficial effect of profound hypothermia (15). The optimal hematocrit during no flow under profound hypothermia is unclear (16).

The last study of this series was the most important (17). Sixty minutes of normothermic hemorrhagic shock was followed by rapid cooling using CPB and 60 mins of cardiac arrest at Tty of <10°C. Complete functional recovery was achieved, and, documented for the first time, the brains were histologically normal.

Clinically, CPB cannot be initiated within the critical 5 mins of recognizable cardiac arrest. A different approach is needed. Rapid placement of an aortic catheter could allow targeting of the brain and heart with a flush of cold fluid. A double-balloon catheter could allow differential flushing of the heart and brain while assisting with hemostasis.

Hypothermia Strategies. Subsequent studies have utilized a single-balloon catheter (Cardeon, Saratoga, CA) for flushing the aorta with isotonic saline, at a rate of 1–2 L/min, starting at 2 mins of no flow. Catheter design seemed to influence outcome; with the opening at the tip, the straight flush resulted in better outcome than that achieved using a catheter with the tip closed and the flush through multiple lateral openings. This flush at 0–4°C could lower Tty by 3°C per minute. The outcome model used included rapid, controlled hemorrhage from aorta and vena cava over 5 mins to cardiac arrest (which was ensured by inducing ventricular fibrillation), and aortic cold saline flush started at 2 mins of arrest, with drainage via the vena cava catheter (Fig. 1). The period of circulatory arrest was varied from 15 to 120 mins (18–21) under preservative Tty levels decreasing from 34°C to 6–10°C. Reperfusion and rewarming were accomplished with closed-chest CPB, primed with Ringer's and dextra 40 in saline.

With cardiac arrest of 15 mins of no flow, saline flush volume of 25 mL/kg (a clinically feasible, portable volume) at 24°C (room temperature) achieved Tty of 36°C and, at 72 hrs, functional normality with histologic damage, whereas the same protocol with saline at 0–4°C achieved Tty of 34°C, and two of six brains were histologically normal (18). With cardiac arrest of 20 mins (19), aortic arch flush rapidly lowered Tty to 34°C and achieved survival to 72 hrs with functional normality and minimal histologic brain damage.

For cardiac arrest of 15 or 20 mins, the catheter balloon was inflated in the descending thoracic aorta for aortic arch perfusion. With longer arrest times, ischemia of the spinal cord, gut, and liver became apparent. Hind leg weakness was observed. The authors found that the most reliable flush method might be the simplest: flush via a large-bore cannula in the femoral or iliac artery to include the entire organism. For circulatory arrest periods of >30 mins, very large volumes of cold flush solution would be required. For example, for a 70-kg adult human, this would translate to 7 L of iced saline, which is feasible for ambulances or emergency departments but not for field medics. For cardiac arrest of 30 mins (20), the flush volume of saline at 0–4°C was increased to 100 mL/kg via the femoral artery to achieve a Tty of 28°C; this achieved functionally normal brains (in some dogs, even histologically normal brains).

Cooling to a Tty of 20°C, 15°C, or 10°C preserved the brain and organism to achieve intact survival (OPC 1) after 60, 90, and in some dogs, even 120 mins of no flow (21) (Fig. 2). All six dogs with cardiac arrest of 90 mins and a Tty of 10°C were functionally normal, with no or minimal histopathologic damage. One dog, after cardiac arrest of 90 mins, one after cardiac arrest of 60 mins, and one normal dog without cardiac arrest had normal cognitive function based on a battery of tests 3 months later. Of concern clinically, however, was that delaying the start of flush to 8 mins of arrest in the 30-min cardiac arrest model negated the preservation achieved with flush starting at cardiac arrest of 2 or 5 mins (22).

To achieve a Tty of 10°C in an adult human with the flush strategy above would require enormous amounts of ice-cold fluid, which would be impractical in the hospital and impossible prehospital. Another approach would be to start with a single, small flush to achieve mild cerebral hypothermia and then to recirculate diluted venous drainage blood, with or without an oxygenator, through a cooler-heat exchanger, to reduce Tty to profound hypothermia (11). Nozari et al. (unpublished observations) found that the recirculation strategy enabled intact survival with full neurologic recovery after 90 mins of cardiac arrest at least as reliably as the initially used one-way flush but with one tenth the volume.

Pharmacologic Strategies. Pharmacologic approaches with novel drugs and solutions would be advantageous for induction of suspended animation by synergizing with hypothermia and, perhaps, decreasing the volume of flush that is needed (23–27). Even if the aorta could be accessed and cold flush initiated within the first 5 mins of normothermic no flow and a drainage catheter inserted into the vena cava, the 10- to 20-L cold solution (0–4°C) estimated to be required for a 70-kg adult human to lower Tty to 10°C (and core temperature to about 20°C) would not be feasible in the field. Although difficult in the ambulance or hospital emergency department, such large amounts of solutions could be stored in a refrigerator.

The same Pittsburgh team conducted

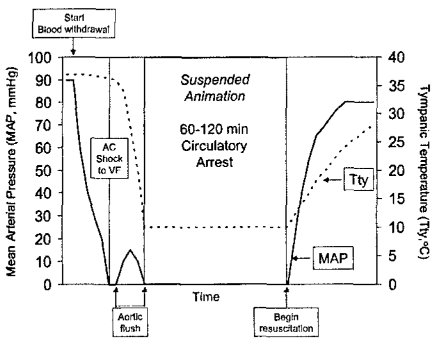

Figure 1. Model of exsanguination cardiac arrest, preservation via aortic flush, circulatory arrest for 15–120 mins, and resuscitation using cardiopulmonary bypass. *AC*, alternating current; *VF*, ventricular fibrillation.

	Overall Performance Category				
Arrest time	**1 Normal**	**2 Moderate Disability**	**3 Severe Disability**	**4 Coma**	**5 Dead**
15 min Tty 34°C	●●● ●●●	●			
20 min Tty 34°C	●●●●	●	●		
30 min Tty 28°C	●●●●	●●●●●*			
60 min Tty 10°C	●●●●				
90 min Tty 10°C	●●● ●●				
120 min Tty 10°C	●●	●	●	●	

Figure 2. Overall performance categories after exsanguination cardiac arrest of 15–120 mins with preservation via hypothermic aortic arch flush. *Tty*, tympanic membrane temperature. *Hind leg weakness.

the first systematic exploration of pharmacologic cerebral preservation potentials of 14 different drugs in 73 dogs (Fig. 3). The model used was 20 mins of exsanguination cardiac arrest with a potentially portable volume of flush solution (25 mL/kg) at ambient temperature, which achieved only mild cerebral hypothermia. In controls, saline flush started at 2 mins of cardiac arrest achieved survival with brain damage (19). In groups of three to six experiments per drug, various doses were flushed into the aortic arch via a balloon catheter, and in some experiments, additional intravenous medication was given during reperfusion with CPB. The drugs were selected and grouped according to six mechanistic strategies (26): 1) delaying energy failure, 2) protecting membrane integrity, 3) preventing structural degradation, 4) regulating protein synthesis, 5) preventing reoxygenation injury, and 6) preserving mitochondria. Selection of drugs and doses was influenced by published beneficial results (mostly in rodents) and guidance by expert consultants. Pharmacologic properties that would allow blood–brain barrier penetration were also considered. The goal was to identify a breakthrough effect (i.e., the majority of dogs in the miniseries to achieve OPC 1 at 72 hrs). None of the 14 drug treatments resulted in a breakthrough effect (23–25) (Fig. 3). Only an occasional dog achieved OPC 1 (but with some histologic damage) after thiopental plus phenytoin or glucose plus insulin. The antioxidant tempol, however, gave a suggestion of benefit (26). Tempol is available and inexpensive and penetrates the blood–brain barrier, but it is not approved by the U.S. Food and Drug Administration. All eight dogs that received 150–300 mg/kg tempol in the aortic arch flush at the start of cardiac arrest achieved OPC 1 or 2 (good outcome), whereas none of the eight control animals achieved good outcome ($p = .03$). Of concern, however, is that histologic damage was not significantly mitigated by tempol. Various explanations for this have been discussed (26). The only negative side effect of tempol, minimal transient methemoglobinemia, was clinically not significant.

One may criticize this exploratory approach because it is not possible to rule out some benefit possibly revealed by larger sample sizes and randomized concurrent controls. The cost and time involvement needed to conduct such studies in large animals would be prohibitive.

Solutions. In the studies described above, isotonic saline solution was used for flush and dextran 40/Ringer's solution for reperfusion via CPB. Solutions designed specifically for profound hypothermia have been explored (27–30). Using the 30-min cardiac arrest model with Tty of 28°C (20), polynitroxylated albumin plus tempol (Synzyme, Irvine, CA) slightly improved neurologic deficit scores and histopathologic damage scores compared with saline, whereas 5% or 25% albumin did not (27). Using the 120-min cardiac arrest model with Tty of 10°C (21), Normosol (a pH-normalized Ringer's solution) was used for cold flush and "Unisol" (two solutions: an "intracellular fluid" with composition designed for stasis and an "extracellular fluid" designed for reperfusion), designed by Taylor et al. (29, 30) (Organ Recovery Systems, Charleston, SC), was used. With these "optimized" solutions, OPC 1 and only minimal to moderate histologic damage was achieved in five of six dogs. Additional studies to optimize the solutions are needed.

Trauma. Exsanguinating hemorrhage in trauma patients does not occur without significant tissue trauma. Nozari et al. (31) explored the above suspended animation approach with trauma added in the form of thoracotomy, laparotomy, and splenic transection. Splenectomy was performed during arrest. The coagulopathy due to hemodilution, hypothermia, and ischemia was greatly worsened by trauma, even with use of fresh donor blood during resuscitation. Nevertheless, exsanguination cardiac arrest of 60 mins plus severe trauma could be reversed to intact survival, but multiple organ failure occurred in several animals. The encouraging finding was that brain histopathology was normal. This suggests that, with prolonged intensive care and rehabilita-

	Overall Performance Category				
Drug	**1 Normal**	**2 Moderate Disability**	**3 Severe Disability**	**4 Coma**	**5 Dead**
Control	•	•••	••••••	••••	
Adenosine			••		
Thiopental	••		••	•••••	
Thiopental Phenytoin	•		••	••••	
Fructose Biphosphate			••	•••	
MK801			••	•••	
YM872			•	••	
Nimodipine			•	•	
Diltiazem			•	•	
Lidocaine			••	•	
Insulin Glucose	•		••	•	
W7			•	•	
Cycloheximide			•••		
Tempol	•••••	•••	•	•	
Cyclosporine A			•	•	

Figure 3. Overall performance categories after exsanguination cardiac arrest of 20 mins with preservation via aortic arch flush and novel pharmacologic potentials.

tion (as could be utilized clinically), long-term intact survival would be expected.

Plasma exchange can decrease the microangiopathy seen in some patients with sepsis and multiple organ system dysfunction. Nozari et al. (unpublished observations), found that plasma exchange not only decreased the organ system dysfunction seen after trauma and suspended animation, but may also have improved neurologic outcomes.

Other Approaches. In addition to the Pittsburgh group, two other groups have explored the concept of suspended animation, although from somewhat different perspectives. Taylor et al. (29) and Bailes et al. (32) were interested in developing a method for protecting the brain during otherwise infeasible neurosurgical procedures. They showed that asanguinous low-flow perfusion of the organism with CPB of >3 hrs, under ultraprofound hypothermia (<5°C), could be survived with normal neurologic function. Specialized fluids were used during cooling, stasis, and resuscitation/rewarming. Long periods of total circulatory arrest were not explored, however. From a clinical perspective, in the exsanguinated trauma patient, intermittent low flow during suspended animation may be helpful for finding bleeding sites and, perhaps, improving preservation, although this remains to be explored.

Rhee et al. (33) have also explored suspended animation in a clinically relevant exsanguination model in pigs. Using readily available equipment, they induced profound hypothermia by aortic flush, both proximally and distally, via a thoracotomy and direct aortic cannulation. Repair of the aortotomy was accomplished during no flow. After total circulatory arrest of up to 40 mins, normal neurologic recovery could be achieved (33). The same group under Alam et al. (34) found normal cognitive function after exsanguinating hemorrhage from a vessel injury and prolonged asanguinous low flow (by CPB) at 10°C.

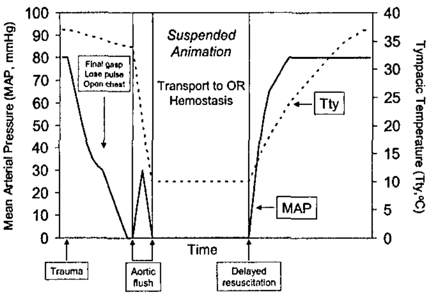

Figure 4. Possible clinical scenario for suspended animation in trauma victims with exsanguination cardiac arrest. As the patient becomes profoundly hypotensive, a last gasp and loss of pulse would be indications for rapid thoracotomy. If cardiac arrest is not rapidly reversed, the aorta can be cannulated and suspended animation can be induced via hypothermic flush to buy time for transportation to the operating room for control of major bleeding and delayed resuscitation using cardiopulmonary bypass. *OR*, operating room.

Cryobiology. Attempts at further extending the so far maximal duration of reversible cardiac arrest of 90–120 mins with hypothermia alone would take suspended animation research into cryobiology. Could one further extend the preservation time by going below 5°C? Profound hypothermia (5–15°C) has been shown in itself not to damage brain tissue (34, 35), but going below 5°C can cause denaturation of proteins and permanent cell damage, irrespective of the damage caused by ischemic anoxia (36). Ultraprofound cerebral hypothermia (<5°C) with special acellular synthetic solutions as blood substitutes, however, has been shown to preserve viability of rat hippocampus (36) and to achieve good outcome in dogs with low-flow CPB (32).

Future Directions

Potential Clinical Trials of Suspended Animation. For traumatic exsanguination cardiac arrest, clinical feasibility trials for the initiation of suspended animation are indicated, at least in emergency departments of major trauma centers (Fig. 4). Later, when appropriate devices become available for initiation of suspended animation outside the hospital, such feasibility trials could become part of emergency medical services research.

During severe hemorrhage without anesthesia, patients become unconscious when mean perfusion pressure decreases to <40 mm Hg, which is also about the point at which pulses are not palpable in large arteries. When apnea then ensues and pulsations are no longer palpable, one can assume cardiac arrest. Frequently, if the patient has had signs of life not long before this, emergency department thoracotomy is performed, particularly for victims of penetrating trauma. If a pulse cannot be rapidly restored, this could be a signal for accessing the aorta and administering the cold flush (i.e., inducing suspended animation). Drainage could be achieved rapidly by opening the right atrial appendage. The other potential approach for access would be cannulation of the femoral artery and vein via cutdown.

Given that the mortality rate for trauma patients who become pulseless from exsanguination and undergo emergency department thoracotomy is near 100% (7), clinical trials cannot be randomized. A reasonable approach would be to induce suspended animation after a brief period of unsuccessful resuscitation attempts, including thoracotomy and open-chest cardiopulmonary resuscitation. As clinical studies begin and experience grows, there are important questions that should be addressed. Who may benefit from expensive and labor-intensive suspended animation? What logistic problems need to be overcome to initiate suspended animation?

Device Development. To take suspended animation outside the hospital, devices for implementation will need to be developed. These devices should include a "smart catheter" to facilitate rapid percutaneous access to the aorta and vena cava, without thoracotomy and a miniaturized cooling-pumping device. Ideally, for portability in the field, the maximally miniaturized cooling source with pump could be developed for dual use: 1) for venovenous extracorporeal cooling for rapid induction of mild systemic or cerebral hypothermia in conditions with circulation (after normovolemic cardiac arrest, hemorrhagic shock, traumatic brain injury, stroke) and 2) for profound hypothermic aortic flush in conditions without circulation (i.e., suspended animation for cardiac arrest).

Other Applications. The main goal of suspended animation development has been to save some of the presently unresuscitable victims of traumatic cardiac arrest. It is worth keeping in mind that the suspended animation approach could also be useful when surgeons and anesthesiologists are unexpectedly losing ground with unmanageable hemorrhage during various surgical operations and for performing otherwise infeasible cardiovascular or neurosurgical procedures.

Summary

In dogs, isotonic saline at 0–4°C, flushed into the aorta at a rate of 1–2 L/min, with drainage of the vena cava, can achieve deep to profound hypothermia of vital organs at a cooling rate of up to 3°C per minute. This achieves preservation of viability of the organism during predictable durations of no flow: cardiac arrest of 15–20 mins at Tty of 30–35°C, cardiac arrest of 30 mins at Tty of 25°C, cardiac arrest of 60 mins at Tty of 15°C, and cardiac arrest of 90 mins at Tty of 10°C. So far, pharmacologic approaches have not resulted in any breakthrough effect on outcome above that achieved with hypothermia, except perhaps the antioxidant tempol. Additional studies of novel drugs and, perhaps, combination therapies remain warranted. The optimal fluids to have in the circulation during circulatory arrest and reperfusions need to be determined. As laboratory studies to optimize suspended animation proceed, clinical trials should be initiated. In addition, devices should be developed to facilitate induction of suspended animation, eventually in the field.

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Smart aortic arch catheter: Moving suspended animation from the laboratory to the field

Lyn Yaffe, MD; David Abbott, BS; Bruce Schulte, BS

The objective of the ongoing smart aortic arch catheter research and development program is to engineer "smart" catheter systems for enabling rapid vascular access and catheter placement, primarily within the aorta, for emergency hypothermia and suspended animation induction (1–6). The catheter systems are being designed and engineered to emphasize easy and rapid vascular access and catheter placement, in a compact and portable system, for use by civilian paramedics, military medics, or other trained first responders. The rapid vessel access devices will ultimately provide the necessary means for inducing suspended animation or preservative-resuscitative hypothermia, initially for use in hospital emergency rooms, then mobile intensive care unit ambulances or helicopters, and eventually for paramedics at the point of injury and in the field for combat medics.

The catheters will have the capability of delivering a large volume of cold (~2°C) saline flush into the aorta within several minutes. Immediate and targeted emergency hypothermia interventions may be able to isolate vital organs such as the heart, brain, spinal cord, and associated vasculatures and to impose a state of clinical preservation until transport can be provided to a facility for acute surgical care and delayed resuscitation. The smart catheter program encompasses stepwise design and development of smart catheter components for vascular imaging, trocar guidance and insertion, catheter placement, cold-flush connections, and monitoring of hypothermia by first responders in the field. Prototype catheter designs, aortic arch ultrasound imaging, three-dimensional position tracking of trocar and catheter tips, and system integration thus far have demonstrated the clear feasibility of rapidly accomplishing smart catheter placement for suspended animation induction. Specific catheter designs and guidance systems provide easy, rapid insertion and placement of catheters within the aorta and thereby facilitate the use of lifesaving emergency hypothermia for otherwise unresuscitable conditions. Initially, catheters are being designed and developed for 1) direct aortic insertion by the trauma surgeon in an emergency room via a thoracotomy site, 2) transthoracic aortic placement by a paramedic in the field using semiautomated ultrasound guidance and magnetic position tracking, and 3) aortic placement via femoral access by a paramedic in the field, initially by ultrasound guidance.

The successful design and development of a smart catheter and its guidance and placement system must provide easy-to-use, safe, and efficacious self-sealing, multiple-lumen, aortic balloon catheters, for both civilian and military trauma scenarios, with sufficient portability for field use at or near the point of injury. The aortic arch balloon catheter system will enable: 1) easy, semiautomated, foolproof insertion, sealing against the aortic wall via thoracotomy or transthoracic access, and guidance and confirmation of ascending, descending, or aortic arch placement; 2) rapid delivery of cold-flush solutions into the aorta from an external reservoir; 3) hypothermic preservation of the brain, heart, and spinal cord; 4) access for continued suspended animation and transition to cardiopulmonary bypass; and 5) access for optimal rewarming and transition to normothermic cardiac function.

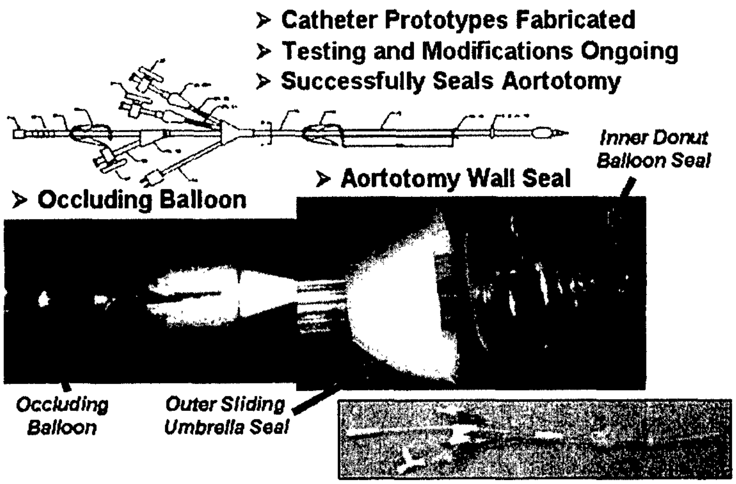

Figure 1. Thoracotomy catheter that has been designed and successfully tested in large animals. The catheter features include a mechanical seal for the aortotomy site consisting of an inner balloon seal and an outer sliding umbrella seal, which together compress the aortic wall to provide a tight seal. The aortic occluding balloon catheter provides aortic access for the delivery of cold-flush solutions.

From Alion Science and Technology, McLean, VA.
Key Words: suspended animation; hypothermia; delayed resuscitation; catheter; aorta; vessel access; portable ultrasound; magnetic position tracking

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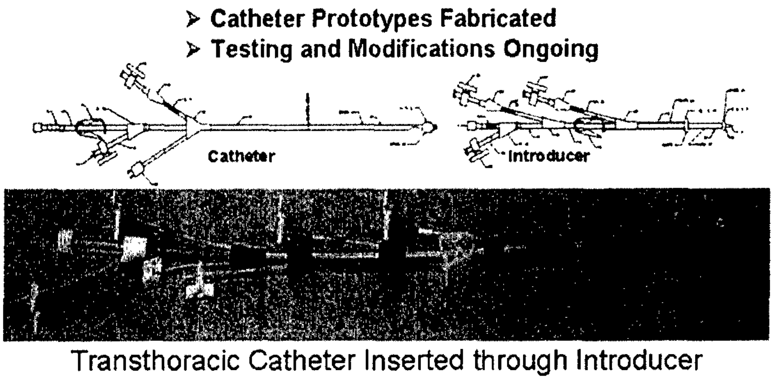

Figure 2. Similar to the thoracotomy catheter, the transthoracic catheter features include an introducer with a mechanical seal for the aortotomy site consisting of an inner balloon seal and an outer sliding umbrella balloon seal, which together compress the aortic wall to provide a tight seal. The transthoracic aortic occluding balloon catheter is then inserted through the introducer, as shown, to provide aortic access for cold-flush solutions.

Designs and Results

Catheters. Currently, the insertion of a catheter through the femoral artery into the aorta or directly into the aorta after left thoracotomy may be very quickly achieved. At trauma centers, surgeons are able to perform open chest heart massage in $\leq$1 min after confirming cardiac arrest and other options are exhausted. Similarly for closed chest scenarios, surgeons are able to cannulate the femoral vessels in humans within 3–4 mins during normovolemic cardiac arrest, while standard cardiopulmonary resuscitation is ongoing, well within the 4–5 mins before serious cerebral ischemic consequences. Ultimately, for exsanguinous no-flow, a direct femoral cutdown, left thoracotomy, or preferably, as proposed in this article, a smart catheter inserted transcutaneously is feasible and needed that quickly facilitates brain and heart cold flush. Rapid and easy vascular or aortic access is critical for the induction of emergency hypothermia and suspended animation at the point of injury to provide a brain and heart cold flush followed by continued fluid cooling. Even for experienced emergency room staff, identification and dissection of peripheral femoral vessels for insertion of arterial and venous catheters may take at least 15 mins in a pulseless patient, or even in a patient with low blood pressure. Typically, this emergency room intervention may be necessary to save the life of a victim using cardiopulmonary bypass for cardiopulmonary-cerebral resuscitation. The smart aortic arch catheter system is being designed for a fast, easy, and safe method to cannulate the aorta for targeted organ cooling. Catheter design and development has been ongoing and will continue by using approved materials for large-diameter balloon catheter and cannula designs. Both single and coaxial catheter designs have been explored. Simulation models have been constructed to produce breadboard configurations of the catheter and guidance systems working within closed-loop models of the aorta and phantoms for initial testing. Catheters and introducers have been fabricated with the assistance of Catheters and Disposables Technology (Minneapolis, MN).

For immediate interventional access, the smart catheter has been designed so that rapid access through the chest wall, from a parasternal approach, may be accomplished with subsequent direct insertion into the aortic arch. On insertion through the aortic wall, the catheter design includes the ability to provide a tight-sealing mechanism at the point of entry through the aortic wall to prevent fluid leaking from the aorta. Balloon-cuff concepts have been conceptualized and designed that may be adapted for this aortic catheter. An aortic arch catheter has been designed so that safe, easy, and rapid access to the aorta may be achieved through the chest wall from a transthoracic, percutaneous, or thoracotomy approach. Prototype, donut-shaped, balloon-cuff concepts have been designed and are used for this aortic catheter as one potential approach (Figs. 1 and 2). These designs maintain tight, leak-proof pressure on each side of the aortic wall. Ultimately, after delayed resuscitation, the point of aortic access would have to be closed surgically. Alternatively, access could be via the femoral artery, with a long catheter being extended to the appropriate position within the thoracic aorta or arch. The benefits of this approach include less potential damage to the aorta and the ability to have a lower placement of the catheter for increased cooling to the lower portions of the spinal cord and abdominal organs in the event of prolonged suspended animation, assuming the availability of adequate volumes of cold fluids.

Guidance and Placement System. For placement of the transthoracic introducer and catheter, portable ultrasound devices have demonstrated the ability to image the ascending aorta, the aortic arch, and the proximal descending aorta. Key images depend on suprasternal notch ultrasound probe placement. The ability to couple the image with access guidance and positioning of an introducer and catheter against the aortic wall was also demonstrated to be feasible using a bench-top prototype and ultrasound phantoms. Studies of the catheter placement challenge revealed the requirement for a location and placement capability based on ultrasound imaging integrated with three-dimensional position tracking. The initial details for integration of real-time ultrasound aortic arch images together with the trocar/catheter tip three-dimensional position have been developed. A software approach to provide this capability has been developed using ultrasound image and position data integration technology available through Cedara Software Corporation (Mississauga, Canada).

The smart catheter guidance, placement, and positioning system has been designed at this point to utilize three-dimensional ultrasound technology based on Cedara Software Corporation's Volume Explorer Framework technology. Position tracking has been successfully demonstrated using Ascension Technology's (Burlington, VT) miniBird magnetic tracking system. Although the smart catheter ultrasound system was initially configured to work with the Terason 2000 laptop-based portable ultrasound system (Terason, Burlington, MA), the current placement, positioning, and tracking system may be integrated with other portable or stationary ultrasound devices. The working prototype system is shown in Figure 3.

At this point in development, the demonstration prototype for the integrated

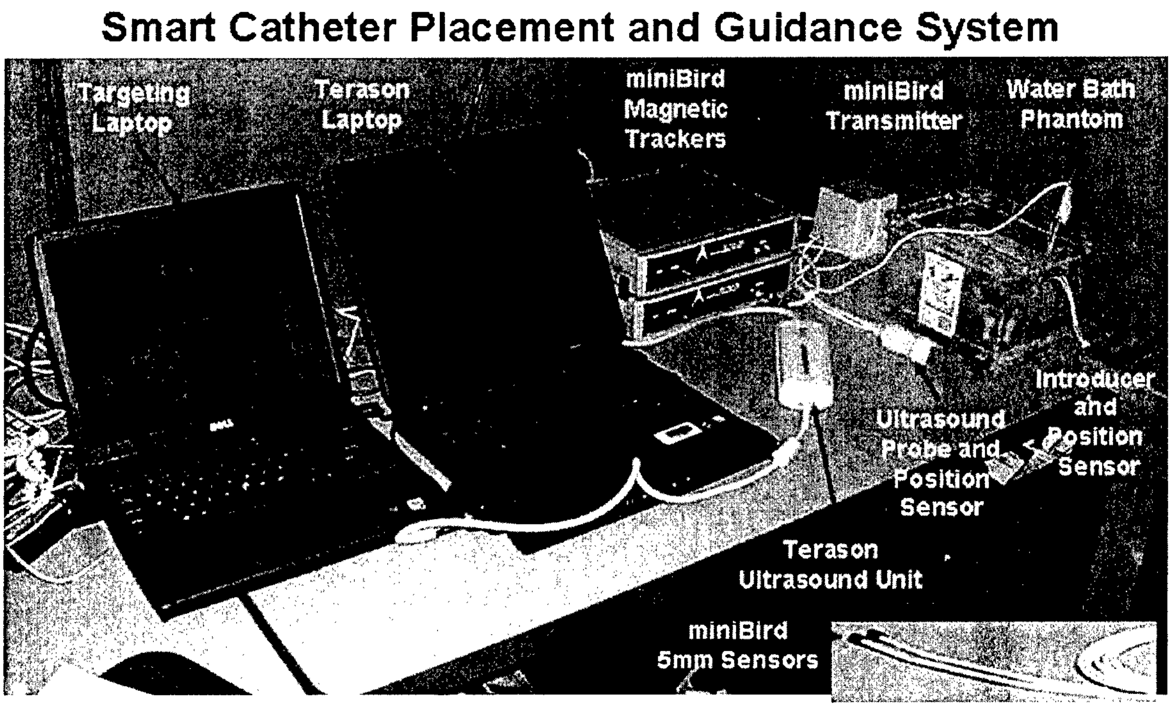

Figure 3. Current smart catheter guidance and placement demonstration prototype system, including the Terason 2000 portable ultrasound unit and ultrasound probe; the Ascension miniBird magnetic trackers, transmitter, and 5-mm position sensors; and ultrasound laptop and targeting laptop. Ultimately, all software and necessary interfaces will be integrated onto a single laptop or LCD for display.

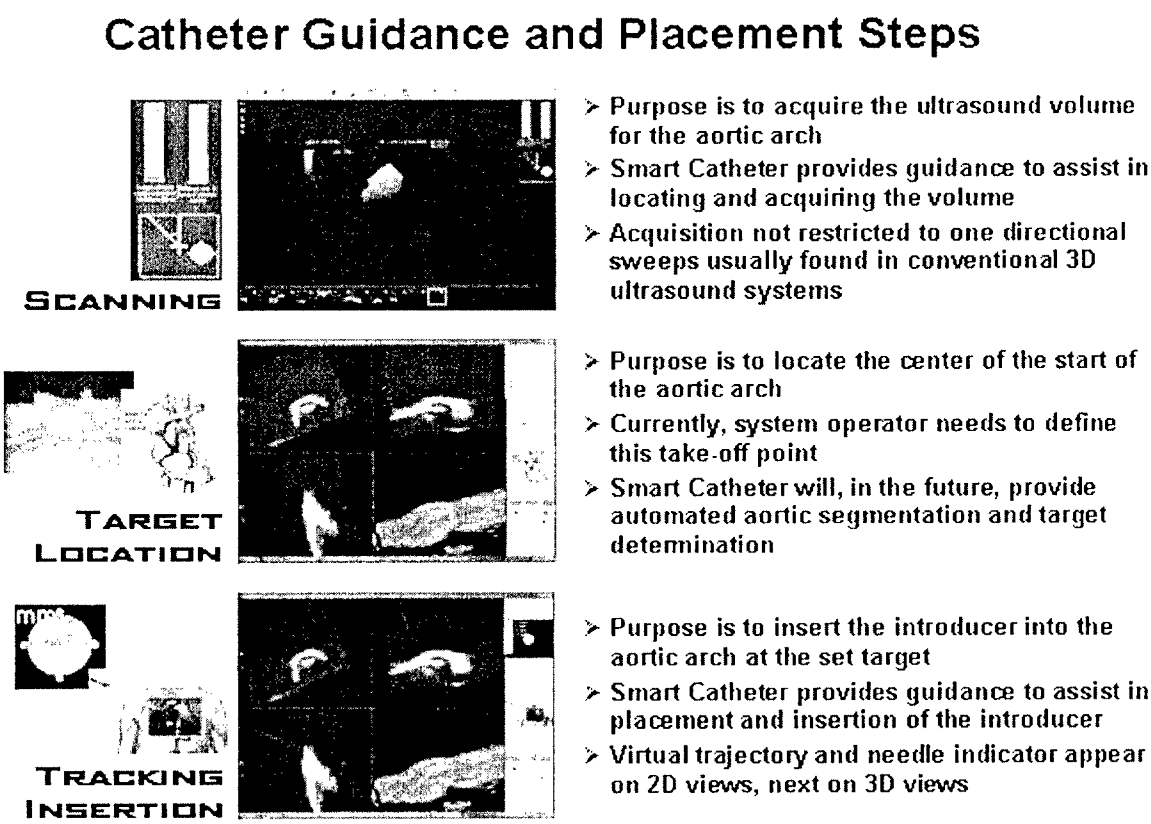

Figure 4. Three primary steps in the ultrasound-based guidance and placement system for the smart catheter into the aorta via a transthoracic approach include: scanning, target location, and tracking insertion. Ultimately, scanning will be continuous and in real time, target location will be fully automated based on aortic arch segmentation as is currently performed, and target insertion will be tracked in real time using a three-dimensional (*3D*) view and virtual trajectory for the introducer/catheter. *2D*, two dimensional.

Moving suspended animation from the laboratory to the field is now fully feasible and achievable in the near future.

guidance and positioning system includes: 1) the Terason laptop ultrasound system and ultrasound probe; 2) the Ascension miniBird magnetic tracker, transmitter, and 5-mm position sensors; 3) Cedara smart catheter–specific software; and 4) smart catheter introducer and catheter. The smart catheter software system divides the catheter placement and positioning procedures into three phases, including acquisition, targeting, and insertion. These functions are detailed in Figure 4, including computer interfaces displayed during the procedures. The design includes automatic target determination of the aortic arch point for catheter insertion. The system currently provides two user interfaces, one relatively complex interface displayed on the laptop and a second simplified interface displayed on a small LCD. Ultimately, when adequate resolution is available, a heads-up display will be employed to provide the user with catheter placement and positioning information.

The current system prototype seeks to incorporate a semiautomated to fully automated aortic/vascular target identification capability with image visualization enhancements. This is being accomplished through automated segmentation of the target of aortic ultrasound image followed by automated location of the catheter insertion target point on the wall of the ascending aorta. Ongoing work will also include the display of the introducer's trajectory in a three-dimensional view. Ultimately, for the transthoracic approach, a smart catheter "bib" concept, as shown in Figure 5, has been designed for stepwise development and will be prototyped. This smart catheter system bib will be placed on the chest and positioned to specific anatomic landmarks to aid in the positioning of the ultrasound probe, the placement of the magnetic positioning reference point, and the entry point for the catheter introducer.

Conclusions

The smart aortic arch catheter project goal is to meet the development challenge for field induction of suspended animation. Catheter seals have been successfully developed and tested, and the feasibility of an ultrasound based guidance, placement, and tracking system for the smart catheter has been demonstrated using the Terason laptop ultrasound system integrated with Ascension's miniBird magnetic position trackers and Cedara's three-dimensional ultrasound imaging and navigation software specifically adapted for the smart catheter system. Based on these initial design developments and prototype demonstrations, moving suspended animation from the laboratory to the field is now fully feasible and achievable in the near future.

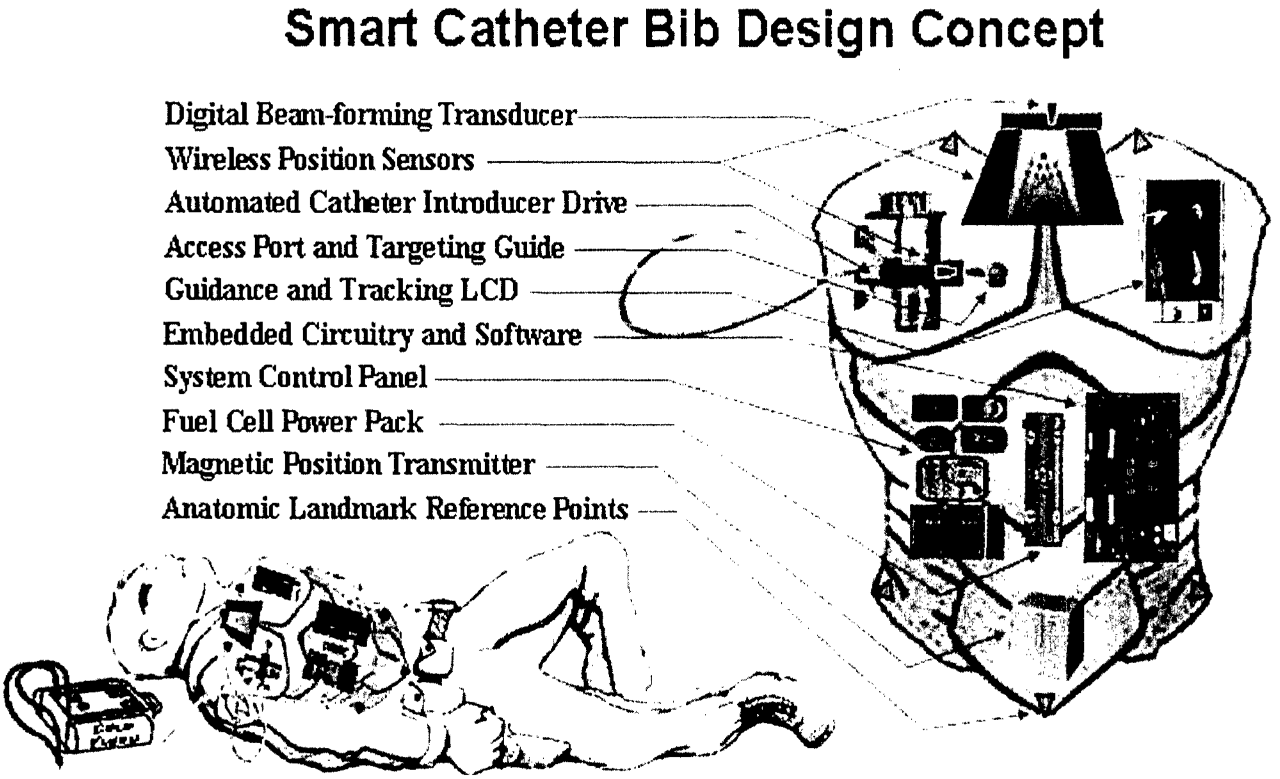

Figure 5. Smart catheter "bib" design concept that has been developed and will be prototyped in a stepwise fashion as key technologies become available. Initially, the bib will include only the ultrasound transducer, access port and targeting guide, guidance and tracking LCD, magnetic position transmitter, and anatomic landmark reference points.

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From Resusci-Anne to Sim-Man: The evolution of simulators in medicine

Ake Grenvik, MD, PhD, FCCM; John Schaefer, MD

Simulators were introduced in education as a tool to make advanced training standardized, less expensive, and without danger to those involved. In 1922 in the United States, Edward Link presented his homemade flight simulator, which became common place in both military and civilian aviation, known as the "Link Trainer." However, several decades passed before this form of training became accepted in medicine.

Already in the early 1960s, Peter Safar had become involved in medical simulation through opportunistic exposure and innovative research. Interested in potential reversal of death from accidents and medical problems causing cardiac arrest, he was disturbed by the poor results of the current resuscitation technique of nonbreathing victims. In discussions with Dr. James Elam, Peter Safar learned that artificial ventilation could be efficiently provided with normal arterial blood gases in anesthetized individuals simply by blowing into the endotracheal tube (1).

In the late 1950s, as chief anesthesiologist at Baltimore City Hospital, Dr. Safar undertook his daring experiments on sedated and curarized volunteers. He demonstrated unequivocally the lack of effect of arm lift/chest pressure ventilation efforts, whereas exhaled air provided through mouth-to-mouth ventilation was not only superior but also resulted in both adequate oxygenation and CO_2 elimination. This study was published in *JAMA* in 1958 (2), and Peter Safar reported on his results at an anesthesiology/cardiopulmonary resuscitation congress in Norway. In 1961, Bjorn Lind and other prominent Norwegian anesthesiologists, who participated in this congress, brought the idea of providing appropriate cardiopulmonary resuscitation training equipment to the attention of Asmund Laerdal, a successful entrepreneur in Stavanger, Norway, whose main business was the manufacturing of toys made of soft plastic materials. Laerdal promptly designed a full-size training mannequin for mouth-to-mouth ventilation. The airway could be obstructed, and it was necessary to use hyperextension of the neck and forward thrust of the chin to open the airway before initiating insufflation of air into the mannequin by mouth-to-mouth technique as described by Peter Safar.

At the recommendation of Dr. Lind, Asmund Laerdal visited Peter Safar in Baltimore for a demonstration of his mannequin. At that time, Kowenhoven, Knickerbocker, and Jude had just published their observation, showing that external chest compression could produce blood flow in cardiac arrest victims. Peter Safar advised Asmund Laerdal to include an internal spring attachment to the chest wall that would permit simulation of cardiac compression; thus, the possibility of training the ABC of cardiopulmonary resuscitation on the simulator was born, with A standing for airway, B for breathing, and C for circulation. This early simulator of a dying victim not breathing and without a heart beat became known as Resusci-Anne, and its utilization rapidly spread around the world.

In 1968, Ake Grenvik of Sweden joined Peter Safar's critical care medicine training program in Pittsburgh. He realized the many problems in training physicians to use proper technique when managing critically ill and injured patients, in whom relatively minor complications could create life-threatening problems leading to death. Through the close collaboration between Peter Safar's department of anesthesiology and critical care medicine on the American side and the Laerdal Corporation in Norway on the European side, Ake Grenvik, too, became very much involved in the exchange of ideas between Pittsburgh and Stavanger. After Asmund Laerdal's premature death of cancer in 1981, his son Tore Laerdal became the leader in their Norwegian family business. He continued the traditionally close relations and support of the Safar group. Having used a Link trainer as a former flight surgeon in the Swedish Air Force, Ake realized the need for advanced simulation training in critical care medicine and made repeated recommendations for the Laerdal Corporation to expand into modern computerized simulation technology. The Laerdal Corporation wisely awaited the right opportunity to start this expansion.

In 1995, only two, and very expensive, human simulators were available in the United States. At that time, Dr. Peter Winter served as chairman of the department of anesthesiology and critical care medicine after Peter Safar, who had withdrawn into his International Resuscitation Research Center for full-time investigations in the field of reanimatology.

Peter Winter had the foresight to acquire one of the available simulators, although at the very high cost of approximately $250,000. Drs. Rene Gonzales and John Schaefer of his Department were appointed director and associate director, respectively, of this simulation center at the University of Pittsburgh. These two ingenious young anesthesiologists designed a far less expensive, much more practical, realistic, and mobile simulation module, which was patented. The Medical Plastics Limited Corporation in Texas assumed responsibility for manufacturing of this new simulator. This company was

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Key Words: simulation-based training; Peter Safar; cardiopulmonary resuscitation; evidence-based education

Simulation in medicine has been greatly influenced by Peter Safar and his collaborators in the University of Pittsburgh Department of Anesthesiology and Critical Care Medicine in the United States and in the Laerdal Corporation in Norway.

later acquired by the Laerdal Corporation, and the Laerdal Sim-Man was born. It is of interest that this simulator is provided at only one tenth of the cost of a human simulator in the mid-1990s.

Because of Dr. Winter's importance to the initiation of the use of human simulators in anesthesiology training, the Pittsburgh simulation center was renamed WISER, standing for the Peter M. Winter Institute for Simulation, Education, and Research. John Schaefer, who is the current director of WISER, has continued to improve the invaluable human simulators manufactured by the Laerdal Corporation. In addition to the full-size Sim-Man, there are also a large number of task trainers available. Gradually, some of these tasks are being incorporated into Sim-Man. Currently, an infant simulator is also in the final stages of completion, named Baby-Sim.

Medical simulators are not only realistic models of real patients, they also involve the most advanced information technology, providing a major simulation center such as WISER with the ability to offer standardized, repetitious training in various invasive procedures and in the decision-making process in crisis management. There are opportunities to acquire performance data online, providing analysis and immediate feedback to the trainees. Scoring is also available, and all performances are video-recorded for immediate or later demonstration to the trainee so that the trainee can see at which points the technique was considered correct or a failure. Statistical analysis of group performance is available, and research in education is therefore a simple task for publication purposes of the efficiency of this new and fascinating training technique.

In conclusion, the evolution of simulation in medicine has been greatly influenced by Peter Safar and his collaborators in the University of Pittsburgh Department of Anesthesiology and Critical Care Medicine in the United States and at the Laerdal Corporation in Norway. This collaboration has already led to cardiopulmonary resuscitation technique and learning on a worldwide basis. What started in cardiopulmonary resuscitation is now continuing, with physicians, nurses, and other healthcare personnel having the opportunity to learn complicated invasive procedures without endangering any patients. Modern, computerized simulators also offer unlimited possibilities for research on education in medicine, and evidence-based training may result in discontinuation of less effective education. Evidence-based education and training in medicine is likely to grow rapidly into a very important domain in our medical schools throughout the entire world.

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National Medical Simulation training program in Denmark

Doris Østergaard, MD

The general purpose of this article is to highlight selected aspects of the integration of simulation-based training in postgraduate medical education in Denmark. In the past decade, a broad range of simulators has been developed and introduced in the education of physicians and nurses. These tools were first used sporadically, but they are now formally integrated in the education of healthcare personnel as part of the former theoretical national compulsory courses for anesthesiologists. Simulation-based training seems to be useful for both novices and experts because the complexity can be controlled and the learners can reflect on their own practice and receive feedback. Postgraduate education is now facing a paradigm shift in Denmark, with assessment on a broader spectrum of competences (1) (discussed later) and training moving away from large-group teaching to interactive learning. From a theoretical point of view, simulation seems to be useful both for practical skills training and for the training of other aspects of competence, such as decision making, communication, leadership, and cooperation. Status for the implementation and perspectives for further use of simulation-based training are outlined.

From the Danish Institute of Medical Simulation, Herlev University Hospital, Denmark.

Key Words: simulation-based training; medical education; Denmark; anesthesiology; clinical practice

The Danish Institute of Medical Simulation is a subdivision of the Department of Anesthesia and is primarily funded by Copenhagen County. To this date, the simulation-based national courses have taken place in this center in collaboration with trained facilitators coming from several hospitals and simulation units in Denmark; the National Board of Health funded this activity.

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Start of Anesthesia Simulation in Denmark

The development of a Danish full-scale anesthesia simulator, Sophus, started in 1991 at the Department of Anesthesiology at Herlev University Hospital in collaboration with Roskilde University, Risoe National Laboratory, and an industrial partner. The idea of using simulation-based training and the concept of crisis resource management came from aviation and was introduced in anesthesia as anesthesia crisis resource management by Gaba et al. (2). The course focuses on skills such as decision making, communication, leadership and cooperation, and stress and resource management. In Europe, these are known as nontechnical skills (3). A Danish version, rational anesthesia, was introduced, and during the next decade, the anesthesia simulator was brought to local hospitals all over Denmark (4). Hence, training took place in an environment familiar to the trainees, and their own anesthesia equipment was used. A number of scenarios with critical incidents were included in the courses, and local procedures and guidelines were tested. Each scenario was followed by a debriefing session guided by a trained instructor, who facilitated the discussion and showed short video recordings of the participant's performance. The purpose of this debriefing session was to allow the anesthesia team of physicians and nurses to reflect on their own performance (medical expertise and nontechnical skills). Simulation was rapidly introduced in all areas of Denmark, and the enthusiasm from the instructors transferred to the teams of doctors and nurses, who evaluated the tool as useful and effective. They preferred this interactive learning to lectures and appreciated these courses, in which nurses and physicians were able to train and learn as a team. Looking back, these courses at local hospitals might be one of the reasons for the successful implementation of simulation-based training in Denmark. The nonthreatening, widespread use of this new tool was important. During the next 10 yrs, simulation was introduced as an educational tool in the formal training programs for physician and nurse anesthetists. In the beginning, the participants were limited to the anesthesia team, and anesthetists played the role of the surgeon; however, new courses for the cardiac arrest team, the neonatal resuscitation team, and the trauma team, including the actual team players, are now frequently run in our hospital (4). The learning concept has changed over the years, and simulation is now also used for building competence, providing the participants with the case in advance so that they may prepare themselves for the scenario.

Why Use Simulation?

Simulation is a technique for interactive activities and includes computer-based learning, practical skill training, full-scale simulation (human patient simulators), role playing, and simulated patients and relatives.

Today, patients often do not accept being used for the purpose of training; rather, they expect the health professionals to be competent. The major advantage of simulation-based training is that patients are neither harmed nor at risk. Simulation allows the trainee to focus, errors are allowed, and repetition is possible. This is not possible in clinical practice, in which the focus is on the patient rather than education. In a simulation scenario, all trainees can obtain the necessary level of competence before the task is performed on an actual patient. Furthermore, a wide range of scenarios, including uncommon but critical events, can be presented to the trainee. Systematic learning and practice of critical job skills and procedures, behavioral skills, attitudes, and values are possible. Last, complexity can be controlled, which allows training of both novices and experts.

From a theoretical point of view, simulation-based training seems to be very useful, as it fulfils the principles for effective learning. It is possible to start at a level consistent with the student's expertise, build on his or her knowledge base, encourage active participation, reflect, and evaluate progress on an individual basis.

Furthermore, it is possible to train individuals to become competent in the difficult setting of critical clinical situations, such as cardiac arrest. Based on the literature, this is needed. Several studies have shown that guidelines for advanced life support are not followed (5, 6), and focus group interviews with junior physicians have made it clear that they feel incompetent as team leaders (Lippert et al., abstract at the ASA Annual Meeting, San Francisco, CA, 2000). The qualifications needed for the anesthesiologists in this situation are theoretical knowledge and the consistent use of algorithms (medical expertise), manual skills and team performance skills (such as communication, leadership, cooperation, and the distribution of workload). These complex skills and attitudes cannot be taught in clinical practice or in lectures but are best taught in small groups and in situations in which the trainees are encouraged to reflect on their own practice.

Educational System in Denmark

In 2001, the Danish National Board of Health introduced new guidelines for postgraduate medical education, addressing a broad spectrum of competencies derived from the seven roles and competences defined by the CanMEDS 2000 Project (1). The seven roles are medical expert, scholar, communicator, health advocate, manager, collaborator, and professional. These roles are in agreement with the six competences described by the Accreditation Council for Graduate Medical Education in the United States. Focus has now changed from being solely on the medical expert role to skills such as communication and leadership. Hence, the question of how to teach the trainees a specific set of knowledge, skills, and attitudes becomes important. The outcome-based educational approach—exemplified by the three-circle model presented by Harden et al. (7)—has been an inspiration to the new anesthesia curriculum in Denmark. The layers in the circle illustrate the layers of competence. The inner circle represents what the trainees should be able to do, the middle circle illustrates the approach of the trainees to the task, and outer circle illustrates professionalism. A total of twelve learning outcomes serve as a framework. Issenberg et al. (8) have illustrated this in the cardiovascular program.

The clinical training program is being redesigned, as is the existing national theoretical program. The National Board of Health is financially responsible for the national compulsory courses that are given during the main part of the educational process. Until 1998, these courses were primarily theoretical courses based on lectures. The Danish Society of Anesthesia and Intensive Care Medicine Educational Committee appoints an individual as being primarily responsible for the learning objectives and hence the content of the courses.

National Compulsory Courses

Due to the growing interest in human factors, anesthesia crisis resource management, and new educational methods, the National Board of Health accepted a supplementary 3-day-long compulsory course in 1998. Thirty-eight residents participated in the first national simulation-based course in clinical decision making immediately before they received their specialist certificate. The program included four full-scale scenarios covering anesthesia and intensive care medicine, lectures, and cases in human factors and in group discussions. The participants were divided into groups of four, and the participants were matched with individuals attending from various hospitals and areas of Denmark. They rotated between the different simulator stations. In the scenarios, the participants had a high degree of exposure to the simulator as they worked in teams of two, while the others either participated as assistant surgeons or as active observers, who were directed to take notes. Debriefing was structured by the facilitator in order to match the learning objectives; however, the trainees could choose the topic they found necessary to focus on. The facilitator selected the parts of the video recording to be seen that were necessary to support learning. At this course, emphasis was on learning and not assessment, and although the simulation setting was new to the physicians, they saw it as a safe learning environment. The evaluations were overwhelmingly positive, and the trainees stated that this was the best of the courses that were offered. Comments included "preferred this type of training to lectures" and "more courses like this and at an earlier stage." After a 2-yr trial period, the course was included as one of the national, compulsory courses. In recent years, advanced technology has made it possible to use not only full-scale simulation, but a variety of different tools, and these are now implemented in the curriculum after a proper needs assessment and description of the learning objectives. Hence, we now use a mixture of case-based learning, computer-based learning, practical skill trainers, full-scale simulation, role playing, and simulated relatives.

The aim for years 2003 through 2006 is gradually to change all the national courses and to integrate new educational tools and methods in the curriculum for doctors during their second, third, and fourth year of training. The responsibility for the courses for first-year residents is regional, and in eastern and southern Denmark, simulation-based training is already integrated in the curriculum for nurses and doctors. This has been possible because of a close collaboration with the doctors responsible for education at all the teaching hospitals in these regions of Denmark.

Does It Work?

In Denmark, evaluation of educational activities is usually carried out solely by measuring the reaction of the trainee, the lowest level of evaluation according to the model of Kirkpatrick modified by Barr et al. (9). The evaluation of simulation-based activities is very positive; the tool is regarded as realistic and helps the trainee to reflect. In the medical domain, however, there is limited evidence of the effect of simulation-based training at higher levels, such as acquisition of knowledge and change in attitudes, changes in organizational practice, or changes in patient outcome (9). The gold standard would be to evaluate whether any learning activity had an effect on patient outcome, but because so many factors influence this variable, this would be difficult to carry out. Because of a lack of familiarity with the assessment of competence in Denmark, we have decided to start assessment of competence in the clinical setting, and a total of 21 specific tests are used (1) for first-year residents. A program for the main part of the education is now being introduced in Den-

We now use a mixture of case-based learning, computer-based learning, practical skill trainers, full-scale simulation, role playing, and simulated relatives.

mark. Assessment of competence in the simulator setting is possible in the future, but the setup needs to validated and the evaluators trained.

Status and Perspectives

In Denmark, the challenge has been to describe a competence-based curriculum focused on a broad spectrum of competences and to integrate new methods of learning and new educational tools, such as simulation-based training, in the curriculum and in the educational plans. The next major challenge is to evaluate the overall effect of this change.

From a theoretical point of view and according to the reaction of the trainees, simulation-based training seems to be useful. The experience the trainee has in the simulator is followed by a debriefing session, in which they can reflect and receive feedback. This is in accordance with the experiential learning cycle described by Kolb (10). Evidence of the positive effect of these learning methods or tools in the medical domain is, however, needed. The quality of educational research is dependent on a certain number of trainees, and this supports the building of simulation centers instead of a local setup. Collaboration between hospitals and simulation centers seems essential for studies of simulation-based training, as previously done by Schwid et al. (11) in the United States. Locally, less advanced techniques, such as simple skill trainers and computer-based learning programs might be available as these are relatively inexpensive and can be used with less instruction than the full-scale simulators. In contrast, expensive simulators and training in complex skills might be centralized for optimal use and most cost-effective training. It is mandatory that educators describe the need for new tools and collaborate with developers on future advances in simulators and educational programs.

Educational activities should be planned after a proper needs analysis and description of goals and objectives. This should be followed by the selections of the proper tools with respect to the context of the educational program and with plans for evaluation. Patient simulation provides a unique opportunity to train clinical skills, decision making, and team building. Hence, some of the simulation-based activities can be arranged as monodisciplinary activities, whereas others, such as team training, should be planned as multidisciplinary training (i.e., trauma team training and advanced life support) (4).

The use of simulation-based training is steadily increasing in our center; 1,200 physicians and nurses participated in full-day simulation-based training courses in 2002. Several hospitals now have access to anesthesia simulators and have started training locally. To this date, the national courses have taken place at our institution with the help of facilitators from other simulator units and hospitals. However, as soon as the local units have acquired competence as facilitators for larger courses, the national courses will be conducted at a regional level.

Collaboration is important to meet the objectives and improve quality. Establishing a simulation center is a complex project, especially with respect to staff education. The role of the facilitator is somewhat different form the role of a lecturer because the most important role is to ensure that learning takes place. It is a challenge to ensure consistency and quality of the activities and to establish quality improvement programs to prove that certain standards are met.

As described previously, we have chosen to assess competence in clinical practice, but in the coming years, assessment in simulation laboratories might be possible after the development of valid and reliable tools and appropriate training of the assessors. First, however, it is essential that we provide scientific evidence for the effect of the training methods used, close the loop between education and clinical reality, elucidate whether training makes a difference in the real world (transfer), and demonstrate that patient safety is improved. Hence, collaboration in high-quality research studies is needed.

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Improving medical crisis team performance

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Human patient simulation is an effective tool in medical education for individuals (1–6) and trauma teams (7). However, there are no reports of training teams to respond to other medical crisis situations. Although not widely reported in the medical literature, many professionals recognize that in-hospital team response to a medical crisis may be chaotic. To try to improve crisis response at the University of Pittsburgh, we created the Crisis TEAM Training course that utilizes Web-based computerized human simulator technology (TEAM is capitalized for emphasis). Our preliminary experience in improving design of a crisis response and training multidisciplinary teams to respond to in-hospital crisis events is described in this article.

Setting

The University of Pittsburgh Medical Center Winter Institute for Simulator Education and Research is a medical education center staffed with four personnel and possessing ten full-body Laerdal SimMan simulators and 12 partial-task trainers. The Institute occupies 7000 square feet of space on two floors in one of the University of Pittsburgh Medical Center hospitals.

Simulator

The Laerdal SimMan simulator is a computer-based mannequin with human physiology emulation capability. For example, the airway is dynamic and can simulate a variety of pathologic conditions. Air flows through the airways. A number of different breath sounds are possible, including wheezes, rales, rhonchi, and normal breath sounds. Heart sounds can be simulated, as can a variety of arrhythmias. The chest rises with respiration, whether "spontaneous" on the part of the mannequin or after manual or mechanical ventilation. A speaker enables the "patient" to speak. Pulses are palpable, blood pressure may be obtained, and fluids are infused into "veins." Pulse oximetry is also possible.

Video Recording Capability

We utilized two video cameras in the simulation patient room using a digital video recorder from EZCam (VT400, Trenton, MI). The SimMan patient monitor video was also captured by the VT400. The EZCam software resident on the digital video recorder allows playback of the cameras and patient monitor onto any computer via a Web browser.

Trainees

We have now trained >200 individuals. All trainees for the Crisis TEAM Training course were advanced cardiac life support (ACLS) certified within 2 yrs of their simulation training. We rationalized that because we wanted to focus on team skills like organization, communication, and interdependency, we needed learners who already had the knowledge of what treatment is required and what skills to provide in emergency situations. The trainees include critical care nurses, respiratory therapists, and physicians. Every session has at least one person from each discipline. Physicians are predominantly trainees, including fellows in critical care medicine and pulmonary/critical care medicine and junior and senior residents in internal medicine, anesthesiology, and emergency medicine. Hospitalists and critical care medicine attendings have participated as well.

Curriculum. The Crisis TEAM Training course consists of four components: 1) a Web-based power point presentation that trainees view before coming to the simulator, 2) a brief didactic session by one of our faculty members, 3) video-recorded simulations, and 4) a facilitator-moderated debriefing, aided by a customized Excel spreadsheet for performance evaluation.

Two of our crisis-response experts developed the PowerPoint presentation that was placed on our Web site. This presentation describes the need for crisis teams as opposed to cardiac arrest teams (the latter respond after cardiopulmonary arrest in an attempt to restore life, whereas crisis teams respond before arrest in an attempt to prevent death). A full description of the process and rationale for it has been reported by several authors and is outside the scope of this discussion (8–12). The presentation reviews some barriers to error-free responses. Importantly, we describe our design for team response: team member roles, the goals for each team member, and the tasks delegated to that role (Fig. 1). We have used automobile racing pit crews as an example of effective teamwork: delegation of task responsibility to specific team members, choreographing of movements so that team members do not interfere with each others' activities, and prioritization of tasks. We also model after Advance Trauma Life Support, which teaches positioning of team members based on skill set and task responsibility. All Crisis TEAM Training participants are required to view the presentation and complete a pretest.

Simulation Scenarios

We created five simulator scenarios for the training sessions (Table 1) and use three different simulated crisis scenarios during each course. No scenario was repeated for any group, and three were used to prevent trainees from discovering before the course all the situ-

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ations they would encounter. Each scenario begins by reading a scenario introduction to a trainee, who would then alert the crisis team. The team then responded and treated the simulated patient. We stopped the response when the definitive treatment was delivered and a triage decision was made, or at 5 mins, which ever occurred first.

Measuring Crisis Response Performance

The primary goal of the crisis team is to achieve mannequin survival. Survival required effective airway management ventilation and maintenance of circulation. In addition, selected scenarios contained a definitive therapy (like defibrillation with 300 joules within 3 mins for ventricular fibrillation) that was considered a key element of successful crisis response.

Sometimes, treatment that saved the life was delivered but other important goals that may have improved outcome (like delivering an appropriate dose of naloxone for opioid overdose) were not completed and a critical incident designation was assigned. Such critical incidents were still considered simulator survival.

Another outcome we measure is the completion of key organizational and treatment tasks. We assess the task completion rate by consensus of the trainees and facilitator after reviewing the recording of their response. A set of 29 tasks was defined, although not every task was required for every scenario. The task completion rate is assigned for the number completed divided by the number applicable for each scenario. The tasks fall into three domains: 1) patient assessment and treatment (e.g., assessing cardiac rhythm, delivering defibrillation), 2) organizing the response (e.g., delivering essential equipment, positioning personnel in appropriate locations, allocating work), and 3) communication (e.g., utilizing closed loop communication, data transfer). We are able to determine source of failure because we assess the task completion rate for each role, each individual, and for the whole team.

Debriefing Sessions. Session scoring is recorded at the time of debriefing on a preformatted Excel spreadsheet. Tasks are determined to be completed or not and are assigned a score of 1 or 0, respectively. We play the video for the first 60 secs, and then the trainees assign scores for each task. The next 2 mins are then reviewed, followed by scoring of the 3-min goals. Finally, the remainder is shown and discussed. The facilitator's role is to ask questions regarding barriers to care, elicit suggestions for improvement, and attempt to focus on the organizing team's response. Team performance rather than individual performance was promoted. For example, the team gained credit even if the individual who completed a task was not responsible for that task. We emphasized the multiple-step processes needed to accomplish "simple" tasks like chest compressions: the team

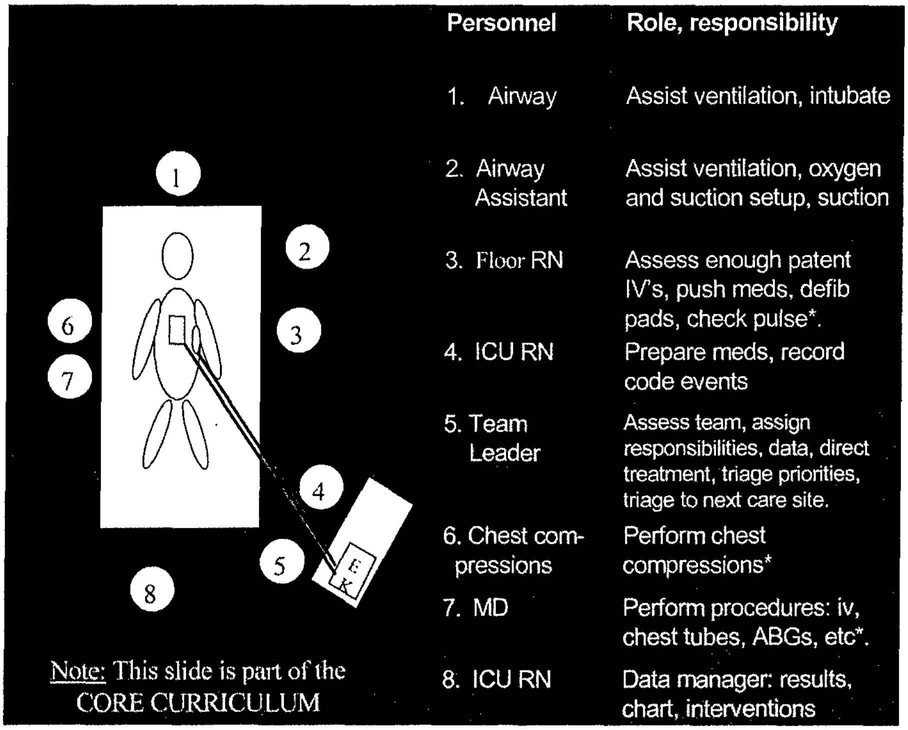

Figure 1. Roles, goals, and positioning for crisis team response. Detailed planning is needed for most effective and efficient team response. *IV*, intravenous; *meds*, medications; *defib*, defibrillator; *ICU*, intensive care unit; *ABG*, arterial blood gases; *RN*, registered nurse; *MD*, physician.

Table 1. Scenarios and definitive treatments

Scenario	Scenario Description	Definitive Treatments	Time Frame, Mins
1	Ventricular tachycardia induced dyspnea	Cardioversion	3
2	Acute myocardial infarction and arrhythmia	Cardioversion	3
		Request for "chest pain team"[a]	3
3	Morphine overdose during patient-controlled analgesia	Mask ventilation	1
		Naloxone[a]	3
4	Acute stroke with mental status change	Mask ventilation	1
		Request for "stroke team"[a]	3
5	Ventricular fibrillation	Chest compressions	1
		Mask ventilation	1
		Defibrillation	3

[a]Denotes goals, which if not completed, permit survival but are a "critical incident."

must 1) place the backboard immediately, 2) allocate two individuals to check for the presence of a pulse, 3) initiate chest compressions, and 4) assess effectiveness of compression.

Hypothesis: Crisis TEAM Training Improves Simulated Survival and Team Organization

Increased task completion rate seems to be associated with improved simulator survival. Among the first ten groups trained, in the first three scenarios of a single training course, survival was 0%. In contrast, the teams successfully treated the mannequin in the third scenario 90% of the time (Fig. 2). This difference was statistically significant (Cochran's Q, 12.6; $p = .002$). The team task completion rate significantly improved from 31% to 89% (Kendall's W, 0.91; $p < .001$) (Fig. 2). Every team showed improvement in their task completion rate, and all but one successfully delivered indicated treatment to cause simulator survival.

It is interesting but disturbing that initially all teams performed poorly even though each team member had previous ACLS certification. We believe our simulator data corroborate the findings of others that ACLS training may not predict future successful performance of ACLS (13, 14).

We suggest that ACLS training is effective in improving knowledge of certain diagnoses and indicated treatment (e.g., recognition of arrhythmias like ventricular fibrillation and the need for defibrillation) but less effective in training skills. In contrast, our simulator exercises focus on individual and team skills directed at organization and task completion (i.e., how to get it done). We have observed that it can be difficult to complete simple tasks when a large number of professionals from many disciplines respond. It is easy for any number of tasks to "fall between the cracks." A crisis situation requires a number of simultaneous, sequential, and coordinated interventions, usually performed by a variable number of responders who are arriving in an uncoordinated order. Our training program attempts to organize these interventions, from selection and placement of equipment to roles and goals of each individual that responds to the crisis.

Our preliminary experience suggests that this model for teamwork is not only feasible but potentially results in superior resuscitation process and outcome. Because we do not train medical procedural skills (like endotracheal intubation) but rather communication and teamwork skills, we believe that our data suggest that these latter skills may be highly important for an effective clinical management of life-threatening emergencies.

Standardization

To organize a crisis team response, the response must be planned in detail and then taught. First, organizers must identify who will respond, what equipment will be available (and how it will get there), what tasks need to be done, in what order, and who will perform them. Equipment should be identical for every response. If each response team uses different equipment, or equipment and medications on the crash cart varies, responders will need to "learn" at every event what equipment is present, where it is located, and how to operate it. This is obviously inefficient and potentially dangerous. Figure 3 shows how confusing various types of defibrillators can be. Second, it is important to consider each step needed to accomplish a task and allocate responsibility for each step. Groups of individuals are more likely to accomplish multiple-step tasks efficiently (once trained) than a single individual because they can delegate the work and perform the needed tasks in parallel. For example, defibrillation is not a task but a goal that requires 14 steps (or tasks) be completed (Table 2).

Third, practice is needed because it helps improve both task delegation and performance. When the team response is choreographed and rehearsed, it may become obvious that certain team members are overburdened or underutilized. Practicing in the simulator setting enables redesign of the response to achieve the best efficiency and effectiveness. One can also use the simulator practice sessions to identify common errors. For example, we found that team members often are incorrect about the presence or absence of a pulse. Because this presence of a

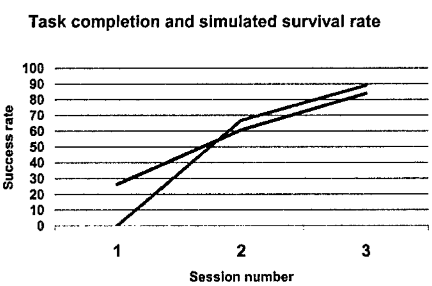

Figure 2. Overall team task completion (*dark line*) and simulated survival rate (*light line*) during first, second, and third scenario encountered by trainees during a 3-hr Crisis TEAM Training program.

Figure 3. A variety of defibrillators with varying capabilities and requirements for accessory equipment. Some defibrillators have pacing capability, others have hands-free technology using defibrillator pads, and others use paddles and require gel pads to augment conductivity. All utilize different operating procedures. With a variety of equipment, it is easy to understand why user errors are common.

pulse is a critical clinical finding, getting it right is essential to make the team deliver the appropriate treatments. We changed our response so that at all times two team members are palpating the pulse, making it less likely that an error will occur. Because two individuals are searching for an event, they are able to cross check findings. Designing in certain redundancies such as this may prevent important errors. Another common error is failure to communicate key data to a decision maker. For example, one person may be observing a pulse waveform on a pulse oximeter at the same time as another person may lose the pulse and report asystole to the team leader. The team leader may incorrectly request chest compressions even though there is evidence that effective circulation already exists. For this reason, we also emphasize proper communication techniques (i.e., identify who needs to know a fact, address that person directly, and the receiver should repeat it back to be sure the message is correct). This speak–repeat back technique has been used in the military and civil aviation for decades to prevent error. The Joint Commission for Accreditation of Healthcare Organizations favors repeat-back methodology for verbal orders for the same reason.

Our training program emphasizes team cooperation more than just leadership. When we began team training, we thought that the chaos during a crisis response was lack of effective leadership. Therefore, in our first efforts, we attempted to train team leaders to both direct tasks to individuals for completion and to direct therapy. We found that this overloaded the team leader, and key tasks failed repeatedly. We then changed our focus to team training. We reasoned that if each team member knew what the team needed, his or her role in the team, and the tasks associated with that role, the team leader instead could focus on assimilating and analyzing data and then directing treatment interventions. This strategy, although tougher to train, resulted in improved performance (Tables 3 and 4). It also more clearly resembles the strategy used by our model, automobile racing pit crews. We have found that team training using a human simulator may increase the success rate for specified tasks, and there is possibly an association between the processes we measured and the simulated outcome. We believe we saw that knowledge of what treatment is needed in a particular circumstance is not enough to ensure overall successful performance, and it certainly does not preclude error. Our experience suggests that practice of a designed response using human simulation, facilitated video recording review and debriefing, and rehearsal of the team response seem to improve performance. Repetition of a specific role by an individual does not explain the improvement, as we ask each team member to assume a different role for each simulated scenario in a training course.

Table 2. Fourteen steps to defibrillation using hands-free electrode pads

1. Take pulse
2. Determine pulselessness
3. Bring defibrillator to bedside
4. Place defibrillator pads on patient
5. Connect defibrillator pads to defibrillator
6. Turn on defibrillator
7. Tune defibrillator to correct electrocardiographic lead (paddles)
8. Look at electrocardiographic tracing
9. Recognize ventricular fibrillation
10. Make medical judgment to defibrillate
11. Select energy
12. Charge defibrillator
13. Clear staff from patient
14. Push defibrillate button or buttons

Future Needs for Crisis TEAM Training Using Human Simulation

We hope this project will trigger much needed investigation. We acknowledge our experience is not a controlled research trial but a quality improvement project that we believe has been effective. We cannot prove whether the response design, the simulator practice, or the debriefing was responsible for the improvement. However, the dramatic improvement in task completion within strict time intervals and simulated survival indicate that further research is warranted. We acknowledge that completion of our Crisis TEAM Training course, like ACLS training, does not necessarily correlate with improved clinical performance and, more importantly, clinical outcome. However, the clinical effect of crisis team training has not been tested yet needs to be assessed. Our scoring system can be utilized in a clinical arena if the crisis response is recorded. Another area of needed research is to assess our scoring system for interrater reliability. It is important to assess precisely performance and track improvement. We hope that because the skills we teach focus on or-

Table 3. First simulation scenario during a course commonly has many deficiencies in completing tasks by all the team members

Sixty Seconds (Session 1)			
Station	Team Member	Items	Complete Task
Airway	XX	Identify self	No
		Check airway	No
		Open airway in <60 secs	No
		Check breathing	No
		Assist ventilation in <60 secs	No
Airway assistant	XX	Identify self	No
		Set up oxygen	No
		Set up oxygen bag	No
		Set up mask	No
Floor nurse	XX	Identify self	No
		Check pulse in <30 secs	No
		Place defibrillator pads in <60 secs	No
		Check intravenous access in <60 secs	No
ICU nurse	XX	Identify self	No
Team leader	XX	Identify self	No
		Assign roles	No
Recorder ICU nurse	XX	Identify self	No
		Hand identification stickers to responders	No
Procedure doctor	XX	Identify self	No
		Check pulse	No
		Assist in cardiopulmonary resuscitation	No
Chest compressions	XX	Identify self	No
		Initiate chest compressions	NA
		Assess adequacy of compressions	NA
		Assess pulse as requested	No

ICU, intensive care unit; NA, not applicable.

Table 4. After team training, task completion rate for each position improves, and the team leader can focus on acquiring and analyzing data instead of organizing the response team

Sixty Seconds (Session 3)			
Station	Team Member	Items	Complete Task
Airway	YY	Identify self	Yes
		Check airway	Yes
		Open airway in <60 secs	Yes
		Check breathing	Yes
		Assist ventilation in <60 secs	Yes
Airway assistant	YY	Identify self	Yes
		Set up oxygen	Yes
		Set up oxygen bag	Yes
		Set up mask	Yes
Floor nurse	YY	Identify self	Yes
		Check pulse in <30 secs	Yes
		Place defibrillator pads in <60 secs	Yes
		Check intravenous access in <60 secs	Yes
ICU nurse	YY	Identify self	Yes
Team leader	YY	Identify self	Yes
		Assign roles	Yes
Recorder ICU nurse	YY	Identify self	Yes
		Hand identification stickers to responders	Yes
Procedure doctor	YY	Identify self	Yes
		Check pulse	Yes
		Assist in cardiopulmonary resuscitation	Yes
Chest compressions	YY	Identify self	Yes
		Initiate chest compressions	Yes
		Assess adequacy of compressions	Yes
		Assess pulse as requested	Yes

ICU, intensive care unit.

ganization and communication rather than procedures like chest compressions, the skills might be better retained. Retention of skills needs to be assessed. The clinical effect of crisis team training has not been tested, but it is worthy of investigation. The final goal of crisis intervention is to save lives, and no assessment of benefit is complete until a clinical improvement is demonstrated. To be sure, our determination of simulated survival is for teaching purposes only and may not correlate with the clinical survival of real patients.

Our crisis response was designed for our institution, and it may not be appropriate at other centers. Nevertheless, we believe our methodology may be universally useful. We believe that team simulation training will improve team performance. The components of crisis-response design, education, and rehearsal using a human simulator may be effective at any site if properly carried out. Tailoring specifics to the resources available is probably appropriate. We are in the process of designing a four-person response team for smaller hospitals, outpatient facilities, and subacute care institutions.

Conclusions

We believe that it is feasible and appropriate to use a computerized human simulator as part of a comprehensive program to teach crisis intervention team skills. Standardization of the equipment, medications, personnel responding, and detailed planned response are necessary prerequisites to teaching a coordinated crisis response. Multidisciplinary teams of healthcare professionals are the norm in clinical care, yet teaching and rehearsing team skills is rare in healthcare education. We suggest that such training improves efficiency and effectiveness of completing key tasks in a crisis situation, and we predict that it will improve clinical outcome.

ACKNOWLEDGMENT

It is said that we stand on the shoulders of our teachers when we make changes to improve. There is no doubt that we who seek to improve resuscitation medicine, and especially those of us at the University of Pittsburgh, are standing on the shoulders of a giant. Standing on his shoulders, we have been challenged to look far into the future and see the road to get there. Peter Safar was the consummate physician, teacher, researcher, and leader. Using his intellect, drive, and wit, he led generations of physicians. He prodded us all to do more, better. This work builds on his work and his vision. We are indebted to him for his support and input. His contribution to making this work possible is rightfully acknowledged.

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Experience with medical student simulation education

William R. McIvor, MD

The anesthesiology department at the University of Pittsburgh School of Medicine has offered human mannequin simulator courses to medical students since 1994 (1). The first simulation course was part of the required anesthesiology clerkship and used a patient simulator with a mathematical model of physiology. Classes focused on inducing general endotracheal anesthesia, managing a patient with a right main-stem intubation, anaphylaxis, and postoperative myocardial ischemia. Scenarios were executed from scripts run by a simulation technician who manipulated the simulator's vital signs. The course was taught with groups of four students and a single simulator; therefore, instructors used the simulator as a demonstration device as they guided participants through the exercises.

Face-mask ventilation was difficult with this simulator because it was not possible to establish an adequate seal. However, because its physiology model required ventilation, many simulation sessions frequently degenerated into unintended ventricular fibrillation codes. Because the scenarios were not programmed, the classes relied on the faculty to be familiar with and facile at executing the scenario scripts. These factors contributed to inconsistent application of the simulator as a teaching tool and probably discouraged new faculty involvement.

Prophetically, the new millennium brought a new simulator, SimMan (Laerdal Corporation, Stavanger, Norway). SimMan has supple, lifelike facial features that facilitate face-mask seals. The Laerdal simulator does not use a mathematical model of physiology; vital signs change either in response to interventions or can be directly entered into the simulator's computer controls.

The simulator's stable physiology and simple controls made it possible to expand the content of simulation courses. In July of 2001, the "Introduction to Anesthesiology" simulation course for first-year anesthesiology residents began. The course curriculum is similar to the third-year medical student course, stressing intravenous induction of general endotracheal anesthesia and task-specific objectives like room setup and anesthesia machine check. In July of 2002, a simulation course was added to the clinical anesthesiology elective for senior medical students. The course helped expand the clinical scope of the elective by emulating scenarios involving neuroanesthesiology, obstetrical anesthesiology, placing and managing double-lumen endotracheal tubes, and preoperative management of patients in congestive heart failure.

Table 1 shows the medical student and first-year anesthesiology resident simulation classes taught in the academic year beginning July 2002. Clearly, the volume of courses and the number of participants and facilitators was expanding. To meet this challenge while improving quality and consistency, the simulation course curricula would have to become more self-contained and easily managed. Our Winter Institute for Simulation Education and Research (WISER) made that transformation possible.

The WISER Center offers a sophisticated infrastructure of physical facilities, simulators for full or partial-task training, the ability to easily measure participant performance objectives, and Web support to enable simulation education. Intuitively, simulation education will benefit from participants beginning the simulation with a thorough understanding of the cognitive goals of the course. Participants are best to be prepared to induce general anesthesia on a simulated patient after they understand the objectives of general anesthesia, drugs used to produce the objectives, and the algorithm for inducing it. The WISER Web site (www.wiser.pitt.edu) displays the course curriculum, including video discussions and demonstrations of cognitive and psychomotor skills. Course surveys are also collected. Responses are stored and analyzed through a secure database, providing instantaneous course feedback. Logistic information such as faculty and participant course assignments and locations are posted. The school of medicine and the University of Pittsburgh Medical Center can also access the Web site to facilitate and simplify course documentation and reporting.

WISER Center personnel also assist in programming SimMan. Running simulations from programs is central to medical student simulation education. Participants work, explore, and experiment during the simulation exercise. By internalizing those experiences, simulation participants presumably develop a deeper, more personalized understanding of the course goals and objectives. A simulation program must respond consistently so that participants' actions demonstrate the course objectives. For example, if a student chooses propofol to induce unconsciousness in a hypovolemic patient, our course objective dictates that the simulator respond with hypotension and tachycardia. The simulator teaches students about the pharmacodynamics of the drug without relying on the facilitator to remember to change the vital signs.

Although consistent response to participant actions makes simulation education possible, the physiology displayed during the simulation makes that education applicable in the real, clinical world. If we ask participants to rehearse clinical skills in a simulated environment, then the onus falls on those who create simu-

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Key Words: medical student education; airway training; human mannequin simulator; simulation education; simulation center

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Table 1. Simulation courses offered to medical students and first-year anesthesiology residents during academic year 2002–2003

Participants	Curriculum	Faculty Contact Hours	Simulator: Student Ratio
150 Second-year medical students	Bag-valve face mask ventilation	75 during 3 days	1:1–1:2
150 Third-year medical students	Anesthesiology clerkship	334 during 96 sessions	1:4
35 Fourth-year medical students	Neurologic, obstetric, thoracic preoperative evaluation	177 during 40 sessions	1:4–1:1
22 First-year anesthesia residents	Introduction to anesthesiology	24 during 3 days	1:4–1:1

Faculty contact hours are number of faculty teaching the course multiplied by hours teaching.

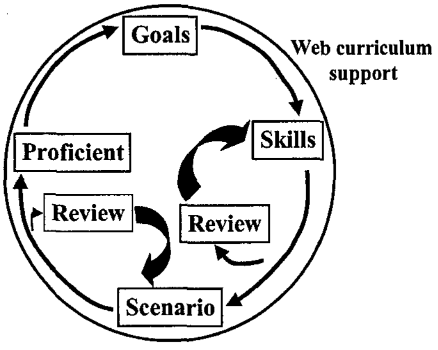

Figure 1. Model of independent study and skill acquisition possible using human simulation courses.

lations to build programs that accurately reflect reality. Human data have been applied to the programming at WISER in both the medical student and difficult airway courses.

WISER courses benefit from objective performance assessment, data compilation, and immediate participant feedback after the simulation. In our nomenclature, the actions that SimMan responds to and registers in a simulation log are called events. The simulator can sense some events like lung ventilation, chest compressions, or palpating pulses or an observer may document this by clicking on that event and filing it in a drop-down menu. Events can trigger a change in the simulation scenario, as when the simulator senses ventilation and starts an increasing oxygen saturation trend, or can simply note in the log that an action was taken (e.g., checking for patient consciousness). Time points for event completion are recorded into the participant's simulation log, to be used during debriefing. Video recording of the participant's performance can be indexed to specific events. Immediate feedback may better help participants recognize the results of their actions.

Collecting performance data provides feedback not only to the participants, but also for the course. Participants not achieving the simulation course's goal may indicate that the goal was unrealistic or that the curriculum was ineffective or flawed. Conversely, if the goals are being achieved too easily, the course might not offer enough challenge, threatening participants' interest and motivation.

Many complex tasks, like inducing general anesthesia, can be divided into component subroutines (e.g., bag-mask ventilation or direct laryngoscopy and endotracheal intubation). Some of these skills can be isolated and acquired using partial-task training before attempting the more complex full task on a simulator. WISER has various airway labs in which students learn and practice bag-mask ventilation, direct laryngoscopy, and endotracheal intubation before attempting an anesthesia induction during a full-scale simulation.

Kollef et al. (2) showed that physicians could hinder patient progress by actively managing care during weaning from mechanical ventilation (2). Likewise, facilitators may hinder simulation participants' progress by aggressively managing the learning experience. To most effectively use simulation education, Socratic, didactic teaching must not be the mainstay of the experience. Students should work through the emulation on their own to internalize and synthesize the experience on the most personal and, presumably, useful level. Figure 1 demonstrates a model of this proposed simulation experience. WISER makes this possible by providing high-quality, continuously accessible descriptions and demonstrations of the cognitive and psychomotor domain of the simulation; reproducible and realistic partial-task training and full-scale simulations; and the prompt, accurate feedback required for such independent study.

WISER courses can also facilitate faculty involvement and increase educational efficiency. Our first simulation courses required faculty to gain familiarity with the simulations, usually through serving an apprenticeship to an experienced faculty member and learning how to run the simulation. In WISER courses, the learning objectives are built into the scenario; thus, the scenario teaches the lessons. Facilitators ensure the objectives are performed correctly and provide appropriate, sensitive debriefing. This obviates the need for a simulation technician because the facilitators can run the simulation themselves. Finally, the "package" nature of WISER courses means that they can be shared between institutions. This could greatly enhance simulation education acceptance and research and test the utility of the application globally.

Second-year University of Pittsburgh medical students participate in a clinical procedures course before beginning clinical rotations. As the name implies, the course teaches students how to perform common clinical procedures (e.g., intravenous and Foley catheter insertion and simple casting of fractures). In April 2003, the first clinical procedures course class to use human mannequin patient simulation, "Introduction to Bag-valve Mask Ventilation" began. This was also the first medical student simulation course designed from the outset to take advantage of the WISER format.

The goal of the bag-valve mask course is that students will ventilate a simulated patient using a bag-valve device. Placing the patient into the sniffing position, obtaining a face-mask seal, recognizing effective or ineffective ventilation, and placing an oral airway are the objectives stressed. Basic mask ventilation skills were chosen for these neophyte clinicians to start their airway management training, help them develop confidence with bag-mask ventilation skills for clinical care, and introduce them to human simulation.

All 150 medical students from the class of 2005 took the 48-min course in groups of 8–12 students. Before coming to the simulation center, they were provided with written descriptions of the relevant airway skills. Participants began the class by watching a 5-min video presentation demonstrating the skills and their proper performance. The video concluded with a demonstration of how to apply the bag-valve mask skills to the actual simulation scenario the students were about to perform. Students then paired up to practice the bag-valve mask skills on SimMan simulators, supervised by an anesthesiology faculty member. After 15 mins of practice, the students performed the simulation scenario designed to assess the performance objectives.

Figure 2 shows an overview of the simulation scenario. Because the bag-valve mask course focuses solely on face-mask ventilation skills, the scenario uses an apneic, monitored "patient" with an Spo_2 of 85% but otherwise normal vital signs (blood pressure, 120/80 mm Hg; heart rate, 80 beats/min). This scenario was chosen to direct student attention toward the patient's airway and need for ventilation and to not overwhelm them with premorbid physiology. It was easy to establish this physiologic scenario with SimMan, and the conditions were maintained effortlessly while the students performed ventilation. Two simulators operated by course facilitators were used for the scenario. Another faculty member proctored participants during the scenario.

The scenario program required that the events "sniffing position" and "oral airway placed" be noted to relieve an imposed upper airway obstruction before students could ventilate the simulator. Those events could be performed in either order (sniffing position first, then oral airway, or vice-versa). Once properly positioned and with an oral airway in place, the students could face-mask ventilate the simulator. When the simulator sensed the first breath, a trend started bringing the oxygen saturation to 100% in 1 min; 100% Spo_2 marked the completion of the simulation.

To protect students from undue distress, 20-sec breaks were written into the simulation program. If a student did not attempt an intervention within 20 secs of starting the scenario or after completing a previous objective, the software triggered a recorded voice stating, "Twenty seconds have elapsed." This cued the proctor to prompt the student about solutions to the simulated problem, such as, "After placing the patient in the sniffing position, what was the next thing done in the video?" It was intended that all 150 students successfully apply bag-valve mask skills during the simulation;

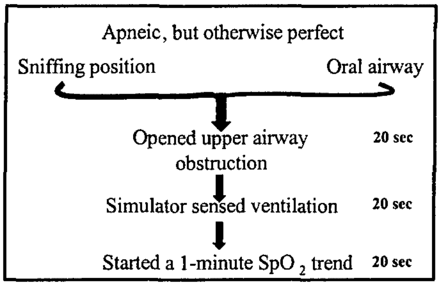

Figure 2. Schematic representing the simulation program used for the introduction to bag-valve mask ventilation course.

Our simulation center (WISER) at the University of Pittsburgh School of Medicine is an evolution, an extension of Dr. Safar's commitment to advancing medicine and its service to our society.

therefore, the faculty prompts were employed to keep students progressing through the scenario with appropriate expedition.

Because the events were entered into the simulation log, time when participants placed the simulator into the sniffing position, attempted bag-mask ventilation, and placed an oral airway were documented. The simulator's ventilation sensor also produced an entry, noting when the first breath was delivered. The logs were saved on a secure WISER database, making the data available for retrospective review. This is an example of the simulator noting a participant's successful completion of simulation course performance objectives.

Because of time constraints and the relative simplicity of the scenario, the students did not review their performance logs after the scenario. Rather, the course director and another faculty member who observed performances debriefed all students after completing the simulation. Students were offered the chance to perform the scenario again, queried about the scenario's difficulty, their anxiety, and their stress while performing it, and given a chance to ask questions or address concerns about their performance.

Exit surveys indicated that the students thought the exercise was relevant to the clinical procedures course and that the scenario was realistic, not too difficult or stressful, and yet not trivial. Students indicated that they had enough instruction and opportunity to practice before the scenario and that they were properly debriefed at the completion. Students were enthusiastic about their performance during the simulation and were looking forward to more simulation courses in the future.

Performance data collected from these simulations could be used toward a myriad of aims. Students' progress can be documented, both for their edification and for their educational institutions'. Standards of performance can also be established, for both individuals and groups. These standards may indicate students who require remediation or extra training, and they can provide rational expectations for future simulation experiences. Given the time it took second-year medical students to ventilate in this isolated airway scenario, reasonable expectations for initiating face-mask ventilation can be applied to future emulations that have this scenario imbedded. In this way, student performance can be analyzed to determine whether problems exist in recognizing the need for an intervention, such as bag-valve mask, or in implementing that intervention.

The bag-mask ventilation course represents a gateway into medical student airway training using human simulation. The Institute of Medicine report, *To Err is Human: Building a Safer Health System* (3), describes the tremendous cost, in dollars and lives lost, from preventable medical errors in the United States. The American Society of Anesthesiology closed-claims study showed that 34% of adverse outcomes from anesthesia were related to respiratory events (4). Inadequate ventilation, esophageal intubation, and difficult tracheal intubation accounted for three fourths of the adverse respiratory events. Assuming anesthesiologists are at least as adept with airway management as other clinicians, the Institute of Medicine report suggests significant improvement in patient safety and mortality could be realized by training all future physicians in airway management. Incidentally, the Institute of Medicine report complimented the decreasing mortality in anesthesiology, which it ascribed in part to developing and adopting practice guidelines and training with human patient simulation.

The ability to practice the proper response to a given clinical situation is a logical application for human patient simulation. Demographics, epidemiology, and statistics can provide insight into which clinical scenarios medical students will commonly face as physicians. Simulation courses can be designed that illustrate rationale, best practices responses to those scenarios. All physicians at some time have been medical students; therefore, a global improvement in patient safety and outcome could be realized by using human patient simulators in training students to respond to anticipated common clinical scenarios, especially those that involve airway management.

Dr. Safar, while chairman of the combined anesthesiology and critical care medicine department, personally attended every Pittsburgh medical student during an endotracheal intubation before his or her graduation. Indeed, our simulation center (WISER) at the University of Pittsburgh School of Medicine is an evolution, an extension of Dr. Safar's commitment to advancing medicine and its service to our society.

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Simulation in medical students' critical thinking

Paul L. Rogers, MD

Developing an educational curriculum that teaches medical students to assess and manage life-threatening illness must be a focus for medical educators because 44,000 to 98,000 patients die each year because of medical error according to the Institutes of Medicine (1). Traditional medical education occurs in the classroom; it is teacher centered, is provided in lecture format, is authoritarian, and is noninteractive. Although this may be an efficient way to cover a large body of knowledge, there are several limitations to this method of instruction. First, the goal of the course is to teach students how to manage unstable patients. These cognitive and psychomotor skills are very difficult to teach in a lecture. Second, classroom instruction is not interactive. When a curriculum is not interactive, it is less likely to engage students, foster interactive discussions, and force students to problem-solve (2). Finally, although a teacher can require students to attend lectures, they cannot always ensure the students will value and incorporate the material into their daily patient care (3).

Teaching using the simulator effectively addresses each of these issues. Students must demonstrate that they can evaluate signs and symptoms, intervene, and evaluate if their treatment has been effective. They must know what to do and demonstrate that they have mastered the cognitive, motor, and communication skills to implement their plan of care. Second, the instruction is interactive, student-centered, and involves active learning, thus increasing students' enthusiasm for learning. Finally, it is easy to get students to value and incorporate safety practices into their management. Because they have had the opportunity to see and experience the adverse events that can occur in the simulated environment, they want to incorporate and avoid these experiences in their patient care. If medical students are given the opportunity to manage crisis scenarios in an environment in which mistakes do not result in untoward outcomes, in which feedback is immediate, and in which they can repeat their performance until they acquire these skills, then perhaps mistakes could be reduced.

Simulators have been used since the 1960s to teach crisis management skills to personnel in military, aviation, space flight, and nuclear power plant operations (4). Recently, the human simulator has given educators a unique opportunity to extend this educational tool to physicians. What initially began as computerized software with separate torso apparatus has evolved into complex, whole-body, computerized mannequins with a functional mouth and airway, allowing bag-mask ventilation and intubation (5). The chest wall expands and relaxes; there are heart and breath sounds and real-time display of physiologic variables including electrocardiogram, noninvasive blood pressure, temperature, and pulse oximetry. The human simulator has individual operator controls for upper airway obstruction, tongue edema, trismus, and reduced cervical range of motion. These computerized human simulators require trainees to integrate cognitive and psychomotor learning along with multisensory contextual cues to aid in recall and application in clinical settings. This type of simulation has been successfully incorporated into curriculum to teach management of obstetrical emergencies (6), management of difficult airway in the operating room (7), crisis management in the operating room (8), and management of unstable patients for critical care medicine trainees (9).

Simulator as an Educational Instrument

Since 1994, the Department of Critical Care Medicine at the University of Pittsburgh School of Medicine has utilized the human simulator to teach medical students crisis management skills. Third- and fourth-year medical students spend a significant portion of their critical care medicine clerkship in the Simulation Center practicing the cognitive and motor skills to manage unstable patients. Examples of some educational objectives for third-year medical clerkship and fourth-year medical student electives are shown in Tables 1 and 2.

Simulator as an Evaluative Instrument

Unfortunately, there are no data to show that instruction using the simulator reduces practitioner error compared with didactic instruction. There is, however, data to show the simulator is a superior evaluation tool, and unlike written examinations, the whole-body computerized simulator gives the teacher an opportunity to evaluate a student's cognitive and motor skills in real time. Because students receive immediate physiologic feedback from bedside monitors and communication from the simulator operator, the students' analytic and evaluative skills are critiqued. Data from our fourth-year medical school elective supports the conclusion that performance-based examinations using the simulator are superior to written examinations because written examinations overestimate the students' ability to reach their stated educational objectives (9).

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Key Words: medical education; medical simulation; crisis management; medical errors; curriculum

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Table 1. Learning objectives for third-year critical care medicine course

Respiratory distress
Evaluate a simulated patient in respiratory distress (tachypneic and hypoxemic)
Initiate appropriate oxygen therapy
Evaluate effectiveness of therapeutic intervention
Demonstrate effective bag and mask ventilation
Insert intravenous catheter for resuscitation
Evaluate patient for potentially difficult airway
Cardiovascular
Evaluate a patient with hypotension
Initiate therapy for a patient with hypotension (initiate intravenous fluid)
Order appropriate diagnostic tests for evaluation of a patient with hypotension
Evaluate effectiveness of therapeutic intervention
Evaluate a patient with sinus tachycardia, develop a differential diagnosis, and order appropriate diagnostic tests
Arrhythmias
Evaluate a patient with sinus tachycardia, develop a differential diagnosis, and order appropriate diagnostic tests
Demonstrate defibrillation of ventricular fibrillation and pulseless ventricular tachycardia
Demonstrate airway management and cardiovascular resuscitation for simulated patients with ventricular fibrillation, ventricular tachycardia, pulseless electrical activity and asystole

Table 2. Learning objectives: Simulation scenarios

Scenario	Educational Objective
Patient with chronic obstructive pulmonary disease, respiratory distress, and hypercarbia who develops pulseless electrical activity after intubation	Recognize hemodynamic consequences of rapid ventilation after intubation Discontinue bag-mask ventilation Check for a pulse Decrease ventilation rate
Patient unresponsive and pulseless	Initiate effective bag-mask ventilation and chest compression Assign specific tasks to specific team members Ask to be told when task is complete Apply advanced cardiac life support algorithm Instruct team members to be prepared for next step
Patient with inadvertent loss of newly placed tracheostomy tube	Assess patient stability Call ear, nose, and throat specialist if the patient is unstable Intubate if unstable
Patient with new-onset substernal chest pain	Assess vital signs Begin resuscitation Qualify characteristics of chest pain Obtain electrocardiogram within 5 mins Begin nitrates, aspirin, oxygen, and morphine (if appropriate) Consult cardiology for thrombolytic or percutaneous transluminal coronary angioplasty

Simulation technology is an effective teaching and evaluation tool for medical education and has the potential to reduce errors in real-life situations.

Conclusions

In conclusion, the human simulator gives students the opportunity to make a clinical assessment, develop a hypothesis, initiate a therapy, anticipate consequences of intervention, communicate treatment goals to staff, and evaluate effectiveness of therapy in a safe environment with the goal of reducing errors in judgment in the future.

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Pediatric simulation: A valuable tool for pediatric medical education

Melinda L. Fiedor, MD

Children are not little adults, and this is especially true when it comes to cardiopulmonary resuscitation. The pediatric patient differs in multiple ways, making resuscitation issues very difficult. First, children have different anatomy and physiology. In terms of resuscitation, the differences in airway anatomy are very important. Overall, the pediatric airway is smaller in diameter and shorter in length than the adult airway. This is significant because a relatively small amount of edema or obstruction causes a large reduction in the diameter of the pediatric airway. Next, the tongue in a pediatric patient is larger relative to the size of the pediatric oropharynx, and posterior displacement of the tongue is a common cause of upper airway obstruction. The relatively large tongue is often a hindrance to a full view of the vocal cords during intubation. Finally, the larynx in infants and toddlers is relatively cephalad in position, and the vocal cords have a lower and more anterior attachment (1). These airway differences are even more important when one considers the cause of pediatric cardiopulmonary arrest; nearly 80% of pediatric cardiopulmonary arrests are respiratory in origin, making pediatric airway management a vital resuscitation skill. Second, medication dosage is another difficulty inherent to pediatric cardiopulmonary resuscitation. All doses of medication in pediatrics are weight based, and this includes the voltage used in defibrillation or cardioversion. Pediatric resuscitation algorithms have another level of difficulty then because doses need to be calculated and cannot simply be memorized. Finally, pediatric cardiopulmonary arrest is a relatively rare event, occurring one tenth as often per year as adult cardiopulmonary arrest. Thus, the ability to practice pediatric lifesaving skills in real time is limited.

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Key Words: resuscitation; intubation; prehospital; team training

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Need for Additional Expertise

These differences in pediatric patients make their resuscitation more challenging than adults. A large body of evidence exists supporting the need for better expertise in pediatric resuscitation. These data come from the two main arenas where pediatric cardiopulmonary arrests occur, the hospital setting and the prehospital environment. A study from Nadel et al. (2) evaluated senior pediatric resident knowledge, technical skills, and perception of confidence related to pediatric resuscitation. The study took place in a large tertiary pediatric hospital, designated a level-1 trauma center, and a regional and international referral center for pediatric subspecialty care. The third-year residents had completed a pediatric advanced life support course in July of their first year and again in October of their third year of training. The study took place in March of the third year. The residents completed the standard pediatric advanced life support examination and 12 short-answer questions. Technical skills were assessed as the resident performed four advanced resuscitation procedures, including airway maneuvers, endotracheal intubation, intraosseous needle placement, and femoral vein access using the Seldinger technique. The residents performed well on the cognitive portion, with a mean score on the pediatric advanced life support examination of 93.2% ± 5.5%. They showed deficits, however, in the performance of technical skills. Only 18% of the residents correctly performed ancillary airway maneuvers, including airway management and bag-valve mask ventilation. Seventy-eight percent of the residents demonstrated errors in endotracheal tube placement. Only one third of the residents successfully demonstrated intraosseous needle placement and Seldinger technique. An earlier study from the University of Washington in Seattle gave similar results (3). A total of 45 pediatric residents previously trained in pediatric advanced life support were observed and scored on four key resuscitation skills (bag-valve mask ventilation, endotracheal intubation, intraosseous catheter placement, defibrillation) and tested with four written scenarios. Regardless of experience or year of training, the residents performed well on the written exam, with a score of 5 (range, 1–5). More than 80% of the trainees achieved the primary end point of a resuscitative skill but performed poorly on the subcomponents of each skill. For example, 39 residents (87%) were able to place the endotracheal tube into the mannequin trachea, but only 27% checked for functioning suction equipment before intubation and only 15% ensured bag-valve mask equipment was available. When a scenario required defibrillation, most residents could discharge the defibrillator (89%), but only 12 (25%) chose the asynchronous mode for a patient in ventricular fibrillation.

Prehospital personnel have similar difficulties with pediatric resuscitation skills. Aijian et al. (4) evaluated prehospital personnel's intubation skills during pediatric cardiopulmonary resuscitation. Of 63 pediatric arrests during a 38-month period, 42 had a paramedic trained in intubation at the scene. In patients >1 yr of age, 66% had endotracheal intubation attempted, with a success rate of only 39%. In patients aged <1 yr, intubation was attempted 38% of the time, with only half of them successful. A similar study in Milwaukee looked at pediatric patient calls requiring intubation during a 1-yr period. Overall, 78% of the patients were successfully intubated, but of those who were not in full cardiopulmonary arrest, only 48% were successfully intubated (5). A controlled clinical trial from Gausche et al. (6) compared the survival and outcomes of pediatric patients requiring airway management by Emergency Medical Services personnel. Patients were either treated with bag-valve mask ventilation or bag-valve mask ventilation followed by endotracheal intubation randomized according to the day of study (odd days received bag-valve mask ventilation and even days received endotracheal intubation). The authors found no difference in neurologic outcome and survival between the two methods of airway management. Of note, however, the results showed only a 57% rate of successful intubation, and of those who were successfully intubated, 58% had complications. The complications included, among others, esophageal intubation, right mainstem intubation, unrecognized tube dislodgement, or choosing improper endotracheal tube size. The consequence of unrecognized tube dislodgement and esophageal intubation was severe as all but one of these patients died. It is clear that expertise in pediatric airway management is lacking and that this is more dramatic when one understands that endotracheal intubation is the only resuscitative skill associated with survival in pediatric cardiopulmonary arrest. Indeed, Losek et al. (7) showed that in 114 pediatric cardiopulmonary arrests, only endotracheal intubation was associated with survival ($p <$ .04). Sirbaugh et al. (8) found that return of spontaneous circulation at the scene of pediatric cardiopulmonary arrest was strongly associated with survival (odds ratio, 0.0; 95% confidence interval, 0–0.08), and in this group of patients, the only variable associated with on-scene return of spontaneous circulation was endotracheal intubation ($p = .032$).

A final point before leaving the literature revisits the lack of experience among those providing resuscitative skills to pediatric patients. A total of 50 Emergency Medical Services advanced life support providers in an urban setting averaged pediatric intravenous cannulation 3.7 times per year, endotracheal intubation 0.3 times per year, and intraosseous access 0.06 times per year (9). Mastery of these skills is difficult, and the scarce opportunity to practice them exacerbates the difficulty.

Opportunity for Simulation

Expertise in pediatric resuscitative skills is lacking, and proficiency in providing these skills can be vital to survival of the pediatric patient. Current resources for pediatric resuscitation education include pediatric advanced life support courses and other courses focusing on advanced skills for the pediatric patient. These courses are offered several times per year and include core lectures, case scenarios, and focused skill stations. The format and curriculum are very good; difficulties include cost, availability, and proximity of these courses to pediatric caregivers. For caregivers in a hospital setting, the opportunity for pediatric resuscitation education is available during intensive care unit or emergency department rotations. Unfortunately, these opportunities are becoming less available because pediatric residency programs have increased emphasis on training in ambulatory/outpatient settings vs. in-hospital management. White et al. provided evidence for this in reporting that in a tertiary care children's hospital, 44% of senior residents reported never having had the opportunity to lead a resuscitation by the end of their training (3).

As mentioned above, the pediatric patient differs significantly from the adult patient, and specific knowledge and skills are required in pediatric cardiopulmonary resuscitation. Studies show pediatric caregivers have suboptimal resuscitation skills, and current educational resources are not sufficient. The solution to this problem lies in an educational tool that is realistic, predictable, and more available. This tool is a pediatric simulator. Simulation has been widely used for many years in the aviation industry and for military training; recently, its use has become widespread in medicine. Simulation has found a place in adult medicine programs, including anesthesiology, trauma, critical care, and emergency medicine. Simulation is ideal for any type of medical trainee because it is available, predictable, and has repeatability. It also offers the opportunity for standardized experience for trainees in an environment in which mistakes can be made and immediately learned from. Specific scenarios can be created that allow the trainee to work through a diagnostic problem while practicing examination skills and performing technical skills. For the pediatric trainee, these characteristics of simulation are quite useful, but even more can be gained from pediatric simulation. An anatomy-specific pediatric simulator will allow for detailed education on pediatric airway management, providing the pediatric caregiver with the resuscitation skills that can be lifesaving in a pediatric cardiopulmonary arrest. Complications such as esophageal intubation or dislodged endotracheal tubes can be duplicated and managed in real time. Specific pediatric physiology can also be reproduced because simulators can be programmed for changes in vital signs and physical exam findings according to the particular scenario in use. For example, a critically ill child in shock presents with tachycardia and weak pulses long before hypotension occurs. Thus, shock in children is often unrecognized because this physiology differs from adults. Simulation provides the ability to duplicate this physiology and give caregivers the opportunity not only to learn but also respond in an appropriate manner.

> *The ability to recognize and evaluate threatening situations, choose appropriate interventions, and then perform required technical skills in real time makes pediatric simulation invaluable.*

Simulation is not only useful for individual trainees, it is also excellent for team training. Pediatric cardiopulmonary arrests are emotionally very charged situations, whether they occur in the prehospital or hospital setting. Team communication and performance can be explored and rehearsed for any type of critical situation with the use of simulation.

In this article, I have focused on pediatric simulation utility in the critically ill child, specifically in situations involving pediatric cardiopulmonary arrest. Many additional aspects of pediatric medicine can be explored using simulation, including physician/family communication, nursing assessment skills, and transport of the pediatric patient. The effect of pediatric simulation will likely be widespread because it is well suited for prehospital personnel, community physicians, emergency departments, and tertiary care facilities. More importantly, simulation will allow for the availability of pediatric-specific individual or team training in which there is little or no other opportunity.

In conclusion, pediatric simulators are educational tools offering distinct advantages in the training of all types of pediatric caregivers. It is an obvious asset in the practice and mastery of procedural skills, but the largest benefit of simulation is the simultaneous integration of technical and cognitive skills. The ability to recognize and evaluate threatening situations, choose appropriate interventions, and then perform required technical skills in real time makes pediatric simulation invaluable.

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Peter's Laws*
For the Navigation of Life

The Creed of the Sociopathic Obsessive Compulsive

1. **If anything can go wrong, Fix It!**
2. **When given a choice - Take Both!**
3. **Multiple projects lead to multiple successes.**
4. **Start at the top then work your way up.**
5. **Do it by the book but be the author.**
6. **When forced to compromise, ask for more.**
7. **If you can't beat them, join them, then beat them.**
8. **If it's worth doing, it's worth doing right now.**
9. **If you can't win, change the rules.**
10. **If you can't change the rules, then ignore them.**
11. **Perfection is not optional.**
12. **When faced without a challenge, make one.**
13. **"No" simply means begin again at one level higher.**
14. **Don't walk when you can run.**
15. **Bureaucracy is a challenge to be conquered with a righteous attitude, a tolerance for stupidity, and a bulldozer when necessary.**
16. **When in doubt, think!**
17. **Patience is a virtue, but persistence to the point of success is a blessing.**
18. **The squeaky wheel gets replaced.**
19. **The faster you move, the slower time passes, the longer you live.**
20. **Death is not the enemy, but occasionally needs help with timing.**
21. **When on thin ice, dance.**
22. **It is up to us to save the world.**

*Safar PJ; Fink BR, McGoldrick KE, eds: From Vienna to Pittsburgh for Anesthesiology and Acute Medicine. Careers in Anesthesiology, Volume V. Park Ridge, IL: Wood Library-Museum of Anesthesiology; 2000: 343.